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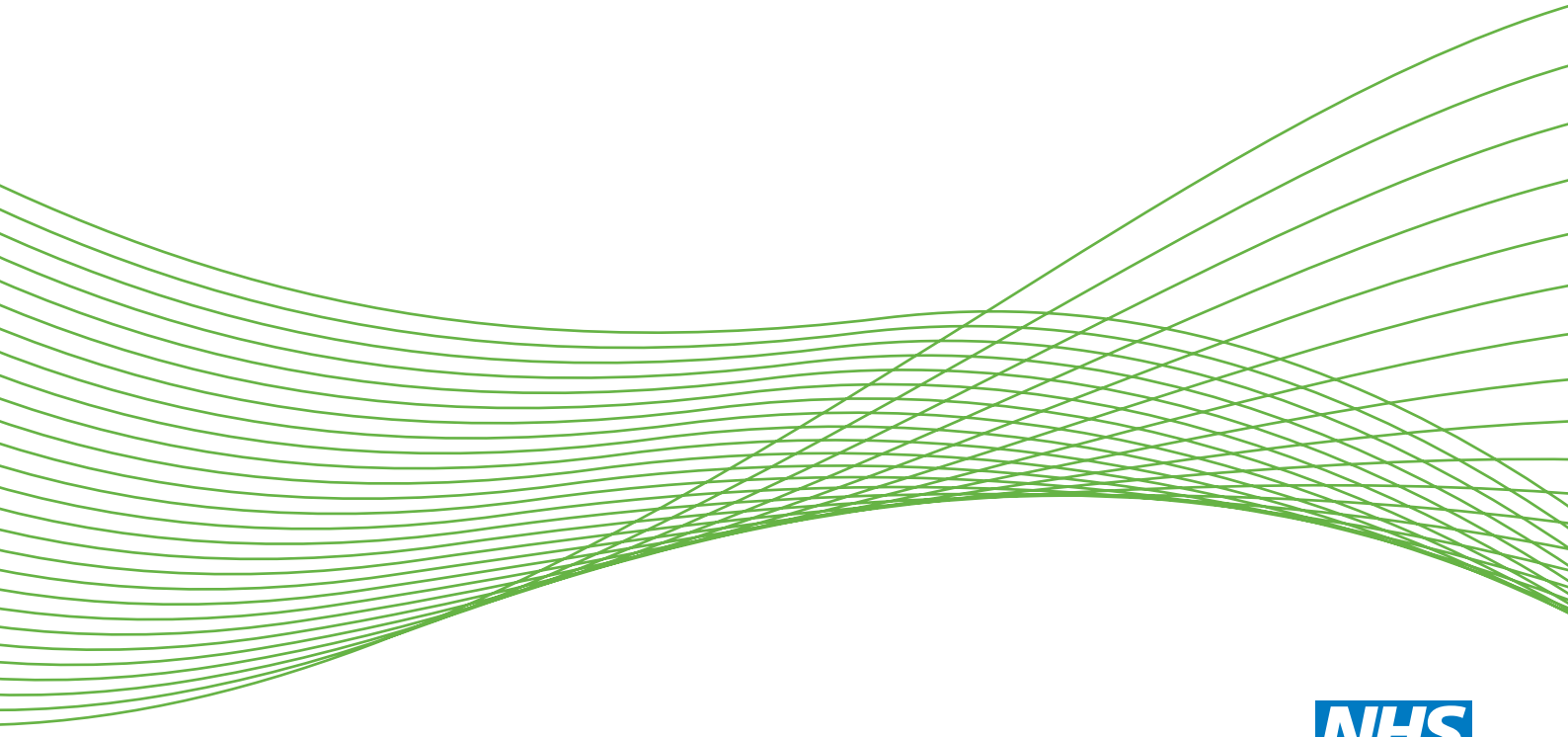

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Karl Claxton,[1,2] Steve Martin,[2] Marta Soares,[1] Nigel Rice,[1,2] Eldon Spackman,[1] Sebastian Hinde,[1] Nancy Devlin,[3] Peter C Smith[4] and Mark Sculpher[1]*

[1]Centre for Health Economics, University of York, York, UK
[2]Department of Economics and Related Studies, University of York, York, UK
[3]Office of Health Economics, London, UK
[4]Imperial College Business School and Centre for Health Policy, Imperial College London, London, UK

*Corresponding author

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Abstract

Methods for the estimation of the National Institute for Health and Care Excellence cost-effectiveness threshold

Karl Claxton,[1,2] Steve Martin,[2] Marta Soares,[1] Nigel Rice,[1,2] Eldon Spackman,[1] Sebastian Hinde,[1] Nancy Devlin,[3] Peter C Smith[4] and Mark Sculpher[1]*

[1]Centre for Health Economics, University of York, York, UK
[2]Department of Economics and Related Studies, University of York, York, UK
[3]Office of Health Economics, London, UK
[4]Imperial College Business School and Centre for Health Policy, Imperial College London, London, UK

*Corresponding author

Background: Cost-effectiveness analysis involves the comparison of the incremental cost-effectiveness ratio of a new technology, which is more costly than existing alternatives, with the cost-effectiveness threshold. This indicates whether or not the health expected to be gained from its use exceeds the health expected to be lost elsewhere as other health-care activities are displaced. The threshold therefore represents the additional cost that has to be imposed on the system to forgo 1 quality-adjusted life-year (QALY) of health through displacement. There are no empirical estimates of the cost-effectiveness threshold used by the National Institute for Health and Care Excellence.

Objectives: (1) To provide a conceptual framework to define the cost-effectiveness threshold and to provide the basis for its empirical estimation. (2) Using programme budgeting data for the English NHS, to estimate the relationship between changes in overall NHS expenditure and changes in mortality. (3) To extend this mortality measure of the health effects of a change in expenditure to life-years and to QALYs by estimating the quality-of-life (QoL) associated with effects on years of life and the additional direct impact on QoL itself. (4) To present the best estimate of the cost-effectiveness threshold for policy purposes.

Methods: Earlier econometric analysis estimated the relationship between differences in primary care trust (PCT) spending, across programme budget categories (PBCs), and associated disease-specific mortality. This research is extended in several ways including estimating the impact of marginal increases or decreases in overall NHS expenditure on spending in each of the 23 PBCs. Further stages of work link the econometrics to broader health effects in terms of QALYs.

Results: The most relevant 'central' threshold is estimated to be £12,936 per QALY (2008 expenditure, 2008–10 mortality). Uncertainty analysis indicates that the probability that the threshold is < £20,000 per QALY is 0.89 and the probability that it is < £30,000 per QALY is 0.97. Additional 'structural' uncertainty suggests, on balance, that the central or best estimate is, if anything, likely to be an overestimate. The health effects of changes in expenditure are greater when PCTs are under more financial pressure and are more likely to be disinvesting than investing. This indicates that the central estimate of the threshold is likely to be an overestimate for all technologies which impose net costs on the NHS and the appropriate threshold to apply should be lower for technologies which have a greater impact on NHS costs.

Limitations: The central estimate is based on identifying a preferred analysis at each stage based on the analysis that made the best use of available information, whether or not the assumptions required appeared more reasonable than the other alternatives available, and which provided a more complete picture of the likely health effects of a change in expenditure. However, the limitation of currently available data means that there is substantial uncertainty associated with the estimate of the overall threshold.

Conclusions: The methods go some way to providing an empirical estimate of the scale of opportunity costs the NHS faces when considering whether or not the health benefits associated with new technologies are greater than the health that is likely to be lost elsewhere in the NHS. Priorities for future research include estimating the threshold for subsequent waves of expenditure and outcome data, for example by utilising expenditure and outcomes available at the level of Clinical Commissioning Groups as well as additional data collected on QoL and updated estimates of incidence (by age and gender) and duration of disease. Nonetheless, the study also starts to make the other NHS patients, who ultimately bear the opportunity costs of such decisions, less abstract and more 'known' in social decisions.

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List of abbreviations

2SLS	two-stage least squares
A&E	accident and emergency
ACCA	Association of Certified Accountants
CARAN	Combining Age-Related and Additional Needs
CBT	cognitive–behavioural therapy
CCG	Clinical Commissioning Group
CEA	cost-effectiveness analysis
CPRD	Clinical Practice Research Datalink
DALY	disability-adjusted life-year
EED	Economic Evaluation Database
EQ-5D	European Quality of Life-5 Dimensions
EQ-VAS	European Quality of Life-visual analogue scale
EU	European Union
FCE	finished consultant episode
GBD	Global Burden of Disease
GDP	gross domestic product
GLS	generalised least squared
GMS	general medical services
GNP	gross national product
GP	general practitioner
GPRD	General Practice Research Database
HA	housing association
HCHS	Hospital and Community Health Service
HES	Hospital Episode Statistics
HIV	human immunodeficiency virus
HODaR	Health Outcomes Data Repository
HRG	Healthcare Resource Group
HSE	Health Survey for England
IAPT	Improving Access to Psychological Therapies
ICD-10	*International Classification of Diseases*, Tenth Edition
ICER	incremental cost-effectiveness ratio
IMD2007	Index of Multiple Deprivation 2007 data set
IV	instrumental variable
LA	local association
LE	life expectancy
LLT	limiting long-term illness
LM	Lagrange multiplier
LSOA	lower super output area
MEPS	Medical Expenditure Panel Survey
MeSH	medical subject heading
MFF	market forces factor
MRC	Medical Research Council
NAO	National Audit Office
NHB	net health benefit
NHS IC	National Health Service Information Centre
NICE	National Institute for Health and Care Excellence
NIHR	National Institute for Health Research
NSF	National Service Framework
OLS	ordinary least squares
ONS	Office for National Statistics
PAS	Patient Access Scheme
PB	programme budgeting
PBC	programme budget category
PBRA	person-based resource allocation
PCO	primary care organisation

PCT	primary care trust
PMS	primary medical services
PROM	patient-reported outcome measure
QALY	quality-adjusted life-year
QIPP	Quality Innovation Productivity and Prevention
QoL	quality-of-life
SHA	Strategic Health Authority
SMR	standardised mortality rate
SNRI	serotonin-norepinephrine reuptake inhibitor
SRCBT	social recovery orientated cognitive–behavioural therapy
SSRI	selective serotonin reuptake inhibitor
SYLLR	standardised years of life lost rate
TCA	tricyclic antidepressant
WHO	World Health Organization
WTP	willingness to pay
YLD	years of life lived with disability
YLG	years of life gained
YLL	years of life lost

Scientific summary

Introduction

The National Institute for Health and Care Excellence's (NICE) comparison of the incremental cost-effectiveness ratio of a new technology, which is more costly than existing alternatives, with the cost-effectiveness threshold is important in assessing whether or not the health expected to be gained from its use exceeds the health expected to be forgone elsewhere as other NHS activities are displaced (i.e. whether or not the new technology is cost-effective).

When NICE issues positive guidance for a new intervention which imposes additional costs on the NHS, the resources required to deliver it must be found by disinvesting from other interventions and services elsewhere. This displacement will inevitably result in health decrements for other types of individuals. Thus, the threshold represents the additional cost that has to be imposed on the system to forgo 1 quality-adjusted life-year (QALY) of health through displacement.

Currently NICE uses a threshold range of £20,000–30,000 QALY gained, and this has remained the case in the NICE methods guidance since 2004. There have been a number of calls for further research on the value of the threshold.

This report details a 2-year project, funded by the National Institute for Health Research (NIHR) and Medical Research Council (MRC) Methodology Research Programme, to develop methods to estimate the NICE cost-effectiveness threshold.

The NICE remit implies a series of characteristics for any empirical research on the threshold:

- Reflect the expected health effects [in terms of length and quality-of-life (QoL)] of NICE guidance through the displacement decisions taken across the NHS rather than what specific services are (or could have been) displaced.
- Facilitate regular updates, based on routinely available data, to reflect NHS changes such as real overall expenditure and productivity. This would encourage accountability through scrutiny by stakeholders and provide predictability for technology manufacturers' investment decisions.
- The nature of service displacement and the magnitude of the health forgone will depend on the scale of the budget impact which should, ideally, be reflected in the value of the threshold.
- Methods should recognise the inevitable uncertainty relating to the evidence currently available for the threshold and reflect its implications for policy.

Study methods

The aim was to develop methods to estimate the NICE cost-effectiveness threshold making use of routinely available data. Objectives were:

i. informed by relevant literature, to provide a conceptual framework to define the threshold and the basis of its estimation
ii. using programme budgeting (PB) data for the English NHS, to estimate the relationship between changes in overall NHS expenditure and changes in mortality

iii. to extend the measure of benefit in the threshold to QALYs by estimating the QoL associated with additional years of life and the direct impact of health services on QoL
iv. to present the best estimate of the cost-effectiveness threshold for policy purposes.

Earlier econometric analysis estimated the relationship between differences in primary care trust (PCT) spending and associated disease-specific mortality. Expenditure came from PB data which allocates the entire volume of health-care expenditure to broad programme budget categories (PBCs) according to primary diagnosis.

This research extended this in several ways including estimating the impact of marginal increases or decreases in overall NHS expenditure on spending in each of the 23 PBCs. These were linked to changes in mortality outcomes by PBC across 11 PBCs.

The results of the econometric analysis were translated into broader effects in terms of QALYs. The first stage linked estimated effects on mortality to life-years taking into account the 'counterfactual' deaths that would have occurred if the population in a given PBC faced the same mortality risks as the general population. The second stage accounted for the health (QALY) effects of changes in mortality due to changes in expenditure reflecting how QoL differs by age and gender. The third stage incorporated those effects on health not directly associated with mortality and life-year effects (i.e. the 'pure' QoL effects) to estimate an overall cost per QALY threshold. The approach uses the estimates of mortality and life-year effects as 'surrogate outcomes' for a more complete measure of the health effects of a change in expenditure. This appears more plausible than assuming no effects of NHS expenditure on QoL outcomes.

The estimated proportional effect on the mortality and life-year burden of disease is applied to measures of QALY burden. Applying a proportionate effect to measures of QALY burden of disease is equivalent to assuming that any estimated effects on life-years are lived at QoL that reflects a proportionate improvement to the QoL with disease. It also allows QoL effects of changes in expenditure to be included, also based on proportionate improvement in the QoL with disease. In those PBCs where mortality effects could not be estimated, the proportional effect of changes in expenditure on QALY burden of disease is assumed to be the same as the overall proportional effect on the life-year burden of disease across those PBCs where mortality effects could be estimated.

The methods planned for the study included a consideration of local data, collected routinely by PCTs, on the types of intervention in which local decision-makers were investing and disinvesting. The aim was to inform the link between the effects of expenditure changes on mortality and impacts on broader health in terms of QALYs. These data may have indicated the types of interventions and services, within a given PBC, on which investment and disinvestment were taking place. Using targeted literature reviews, estimates of QoL for those activities may have been identified. However, it was established that there were limited data available at a local level to facilitate this type of analysis, so other data sources were used for this purpose.

Central or 'best' estimate of the threshold

The most relevant threshold is estimated using the latest available data (2008 expenditure, 2008–10 mortality). The central or 'best' threshold is estimated to be £12,936 per QALY.

Which programme budget categories have the greatest influence on the overall threshold?

Although the 11 PBCs where a mortality effect of changes in expenditure could be estimated only account for 50% of the change in overall expenditure, they account for 78% of the overall health effects. The other 12 PBCs, where mortality effects could not be estimated, account for an equal part of a change in overall expenditure (50%) but only 22% of the overall health effects (i.e. the cost per QALY estimates associated with a change in expenditure in these PBCs are, in general, much higher).

Insofar as investment and disinvestment opportunities in these PBCs might have been more valuable (offered greater improvement in QoL) than suggested by the implied PBC thresholds, the overall QALY effects will tend to be underestimated and the overall cost per QALY threshold will be overestimated.

The overall threshold of £12,936 may be conservative (i.e. could be overestimated) with respect to health effects in PBC5 (mental health disorders), which accounts for a large proportion of the change in overall expenditure (18%) and contributes most to the overall health effects (12%) compared with other PBCs. The cost per QALY associated with this PBC is based on an extrapolation rather than observations of the direct impact of changes in expenditure on QoL. Available evidence suggests that the investment and disinvestment opportunities in mental health may have been more valuable than its implied cost per QALY.

How uncertain are the estimates and what are the implications?

Simulation methods were used to reflect the combined uncertainty in the various estimates from the econometric analysis. This indicated that the probability that the overall threshold is < £20,000 per QALY is 0.89 and the probability that it is < £30,000 per QALY is 0.97.

As the consequences of overestimating the threshold are more serious than underestimating it in terms of population health, a *policy threshold* will be lower than the mean of the cost per QALY threshold (i.e. lower than £12,936) to compensate for the more serious consequences of overestimating the 'true' value.

There were other ('structural') sources of uncertainty associated with the estimated threshold, specifically relating to the choice of econometric models and identification of causal effects. Although all the models passed the relevant tests of validity, there remained some uncertainty about the validity of the instruments. This structural uncertainty constituted a greater part of the overall uncertainty associated with the mortality effects of changes in expenditure, but the central estimate of the cost per QALY threshold was robust to this uncertainty.

The method of analysis used to link the effects of changes in expenditure on mortality to a fuller measure of health expressed in QALYs was also subject to uncertainty. A preferred analysis (or scenario) was identified as making the best use of available information, with assumptions appearing more reasonable than the available alternatives and providing a more complete picture of the likely health effects of a change in expenditure.

A critical issue is whether, on balance, the central or best estimate is likely to be an underestimate or overestimate of the cost per QALY threshold. Although other assumptions and judgements are possible that retain some level of plausibility, they do not necessarily favour a higher threshold. Indeed, when considered together, they suggest that, on balance, the central or best estimate of £12,936 is, if anything, likely to be an overestimate.

There are some reasons why the central estimate of the QALY threshold might be underestimated. First, in calculating life-year effects it is assumed that those deaths averted by a change in expenditure returns the individuals to the mortality risk of the general population (matched for age and gender). There are a number of other reasons why the central estimate might be overestimated. For example, the health effects of a change in expenditure are restricted to the population at risk during 1 year. This also means that the health effects of changes in expenditure which reduce incidence (prevention of disease) will not be captured either. A more formal and longer lag structure in the estimation of outcome elasticities would be likely to capture more health effects of a change in expenditure.

The effect of other assumptions that have been necessary are more ambiguous, although some evidence suggests their net effect may be conservative with respect to health effects of changes in expenditure.

The impact of investment, disinvestment and non-marginal effects

The central estimate of the cost per QALY threshold is based on estimates of the health effects of changes in expenditure across all 152 PCTs, some of which will be making investments (where expenditure is increasing) and others making disinvestments (where expenditure is reduced or growing more slowly).

The threshold is, however, likely to differ across these different types of PCT. It would be expected that, other things being equal, more expenditure would increase health but at a diminishing rate. Therefore, the amount of health displaced by disinvestment would be expected to be greater, and the associated threshold lower than the central estimate. Conversely, the health gained from investment would be expected to be lower, and the associated threshold higher.

This was examined by re-estimating the outcome and expenditure effects separately for those PCTs where their actual budget is under the target allocation from the Department of Health resource allocation formula (i.e. those under greater financial pressure and more likely to be disinvesting than investing), and those that are over target (under less financial pressure and more likely to be investing than disinvesting).

The results confirm these expectations. The health effects of changes in expenditure are greater when PCTs are under more financial pressure and are more likely to be disinvesting than investing. The analysis suggests that budget impact not only displaces more valuable activities within each PBC, but that overall expenditure tends to be reallocated to PBCs which can generate more health. Although further research might enable a quantitative assessment of how the relevant threshold should be adjusted for the scale of budget impacts, the qualitative assessment seems clear: the central estimate of the threshold is likely to be an overestimate for all technologies which impose net costs on the NHS (almost all technologies appraised by NICE); and the appropriate threshold to apply should be lower for technologies which have a greater impact on NHS costs.

How does the threshold change with overall expenditure?

The same methods were used to consider how the cost per QALY threshold is likely to have changed from 2007 to 2008 as overall expenditure has increased. This provides some insights into how the threshold might be expected to change over time as, for example, overall expenditure and NHS productivity changes.

This has implications for a judgement about the appropriate frequency of periodic reassessment of the cost per QALY threshold. Other things being equal, the threshold would be expected to increase following a rise in overall expenditure, although this will depend on whether or not there is discretion over how additional resources can be spent. However, insofar as the productivity of those activities that are valuable to the NHS also improves through innovation, the threshold will tend to fall. So, the net impact of these two countervailing effects on the threshold cannot be determined a priori.

Differences in the estimated thresholds between 2007 and 2008 were assessed. Although overall expenditure increased by 6% between 2007 and 2008, which represented real growth of 2% in 2007 prices, the overall threshold for all 23 PBCs fell by 5% in nominal terms and by 8% in real terms.

The reasons are complex but reflect changes in productivity, which differ across PBCs, but also a general reallocation of a change in overall expenditure towards those PBCs that appear more valuable in 2008. Given the uncertainty in estimation, subtle differences between 2007 and 2008 should not be overinterpreted. This analysis does suggest, however, that the overall threshold will not necessary increase with growth in the real or even nominal NHS budget. This suggests that the threshold is more likely to fall at a time when real budget growth is flat or falling and PCTs find themselves under increasing financial pressure.

What type of health is forgone by approval of a new technology?

The methods of analysis can identify not only how many QALYs are likely to be forgone across the NHS as a consequence of approving a technology which imposes additional costs on the NHS, but also where those QALYs are likely to be forgone and how they are made up (i.e. the additional deaths, life-years lost and the QoL impacts on those with disease).

As an example, based on the 2008 central estimate of the cost per QALY threshold (£12,936), the approval of ranibizumab (Lucentis®, Roche) for the treatment of diabetic macular oedema (prior to the Patient Access Scheme agreement) would have imposed additional annual costs of up to £80M on the NHS each year and been likely to displace 6184 QALYs elsewhere in the NHS. This forgone health is likely to be made up of 411 additional deaths and 1864 life-years forgone, most of which are likely to occur in circulatory, respiratory, gastrointestinal and cancer PBCs. However, much of the total health effect of these additional costs (4987 QALYs) is associated with QoL forgone during disease which is most likely to occur in respiratory, neurological, circulatory and mental health PBCs.

Conclusions and implications for practice

The research presented here goes some way to providing an empirically-based and explicit quantification of the scale of opportunity costs the NHS faces when considering whether or not the health benefits associated with new technologies are expected to be greater than the health that is likely to be forgone elsewhere in the NHS. As such, it provides a basis for determining the appropriate threshold for NICE decisions as well as those made centrally by the NHS and Department of Health more generally.

The methods presented can be used as a framework for further empirical work as additional and more appropriate data emerge in the NHS. They also offer a basis for threshold estimation in other health-care systems with budget constraints or limits on increasing expenditure.

The study also starts to make the other NHS patients, who ultimately bear the opportunity costs of such decisions, less abstract and more ‘known’ in social decisions. As who happens to be known or unknown is only a matter of perspective, time and ignorance, ethical and coherent social decisions require that both should be treated in the same way. These methods contribute to removing some of the ‘ignorance’ and making the unknown more real.

Research recommendations

There is a need to update estimates of the threshold with more recent and future waves of expenditure and mortality data.

If other aspects of social value are applied to health benefits of a new technology they must also be attached to the type of health that is likely to be forgone due to additional NHS costs. The methods developed here can be extended to allow weights to be also attached to the type of health that is forgone and estimate the wider social benefits that are likely to be lost when the NHS must accommodate the additional costs of new drugs.

We have demonstrated that these methods of analysis can be applied to QoL data collected as part of patient-reported outcome measures (PROMs). This type of analysis could be applied to these data in key PBCs as PROMs are rolled out providing some evidence about the QoL effects of changes in PBC expenditure.

A key PBC is mental health. Currently outcomes data that could be linked to measures of QoL are routinely collected in primary care. In principle, the same methods of analysis can be applied to these data once they are made available providing some evidence about the QoL effects of changes in mental health expenditure.

Improved and more recent estimates of incidence (by age and gender) and duration of disease will soon be available from the recently published updated World Health Organization Global Burden of Disease study. These data could be used when the threshold is re-estimated for later waves of expenditure data. Alternatively, estimates could be based on Clinical Practice Research Datalink data.

Estimating a more complex lag structure based on the evolving panel data would provide valuable evidence about the duration of the health effects of changes in expenditure. The recent release of census data for 2011 may allow a panel model to be estimated allowing better control for unobserved heterogeneity across PCTs as well as exploiting variation in outcomes, expenditure and other covariates over time. The formation of Clinical Commissioning Groups (CCGs) in 2013 will make the time series problematic for waves of expenditure after 2012 unless it is possible to match CCG and PCT boundaries.

If PBC expenditure and outcome data are available at CCG level (as well as covariates and suitable instruments), it might become possible to estimate outcome and expenditure equations simultaneously across PBCs. This would enable more of the likely health effects of changes in expenditure to be reflected in the analysis.

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Chapter 1 Introduction

Policy context

A comparison of the incremental cost-effectiveness ratio (ICER) of a new technology with a cost-effectiveness threshold is not the only consideration when the National Institute for Health and Care Excellence (NICE) and its advisory committees issues guidance. However, it is an important one as it allows an assessment of whether or not the health expected to be gained from the use of a technology exceeds the health expected to be forgone elsewhere as other NHS activities are displaced. For this reason a comparison of the ICER of a technology to a threshold range is a critical part of the reference case in the NICE *Guide to the Methods of Technology Appraisal*[3] and is often taken to be the starting point for deliberations about other considerations including judgements of social value. Therefore, the value of the threshold is critical to the assessment of whether or not technologies can be regarded as cost-effective. This is also true for other NHS resource allocation decisions which potentially impose additional costs on local NHS commissioners.

Estimating the cost-effectiveness threshold

A key part of NICE's remit is to make decisions which are consistent with the efficient use of NHS resources. In the context of the NHS budget constraint, a consideration of efficiency has to reflect the implications of imposing additional costs on the system which will displace existing services thus leading to health decrements for patients other than those benefiting from the new technology being appraised. The cost-effectiveness threshold is an estimate of health forgone as other NHS activities are displaced to accommodate the additional costs of new technologies. A national decision-making body such as NICE needs an estimate of what is likely to be forgone across the NHS as we currently find it.[1] Of course, this will change as circumstances and the NHS change; tending to rise with increases in budget and health-care costs but tending to fall with increases in the productivity of health technologies and the efficiency of the NHS in general (including better local commissioning decisions).[2] A body such as NICE cannot and does not necessarily need to know what *specific* services and treatments will be displaced in particular localities or who will actually forgo health.

What is required, therefore, is an accountable and empirically-based assessment of the health that is likely to be forgone on average across the NHS. Currently NICE uses a threshold range of £20,000–30,000 per quality-adjusted life-year (QALY) gained, where additional considerations are required towards the upper bound.[3] The empirical basis of this range of values is very limited and there have been calls for further research in this area.[4] Explicit scientific methods are required which will provide accountability so that estimates can be scrutinised by a range of stakeholders. As estimates of the threshold will need to be periodically revised, methods which make best use of routinely available NHS data are needed. As well as accountability, this will provide more predictability in likely changes to the threshold for the investment decisions of technology manufacturers.

Aims and objectives

The aim of this research is to develop and to demonstrate methods to estimate the cost-effectiveness threshold for the NHS which makes best use of routinely available data. Methods are required which can capture the impact of a change in expenditure on length and quality-of-life (QoL), indicate how estimates of the threshold have changed over time, reflect uncertainty in any estimates and assess its implications,

and indicate the impact of increases or decreases in spending. The project also aims to discuss options for developing data sources in the UK to estimate the threshold more precisely over time.

The research has four main objectives:

i. informed by relevant literature, to provide a conceptual framework to define the threshold and the basis of its estimation
ii. using programme budgeting (PB) data for the English NHS, to estimate the cost per years of life gained (YLG) on average across the NHS, for marginal changes in budget
iii. to extend the measure of the health effects of changes in expenditure by estimating the QoL associated with additional years of life and the direct impact of health services on QoL
iv. to synthesise this work to bring evidence on life-years and QALYs together, to present the best estimate of the cost-effectiveness threshold given existing data, to show the implications of the uncertainty in the current evidence and to provide recommendations for future data collection and analysis.

Report structure

The main report is set out as a series of chapters, most of which are linked to more detailed analysis in separate appendices. *Chapter 2* provides a policy context for the research and a conceptual framework for the subsequent empirical work. *Chapter 3* outlines a simple theoretical model and associated econometric analysis of PB data to estimate the link between changes in overall NHS expenditure and mortality. *Chapter 4* considers a range of analyses to extend the measure of health effect from mortality to YLGs and to QALYs. *Chapter 5* draws out the main conclusions and insights from the research.

Chapter 2 Policy context and conceptual framework

Introduction

The purpose of this chapter is to provide the foundation for the empirical chapters that follow. It addresses a series of questions regarding the nature of the cost-effectiveness threshold that NICE use to guide its decisions, and the principles of how it should be estimated.

The chapter is informed by the results of a systematic literature search relating to these questions. Details of the methods and results of that search, together with a summary of the papers identified, are provided in *Appendix 1*. In brief, the search uses a 'pearl growing' method to identify relevant papers. This identifies a number of initial key articles ('pearls') on the basis of expert advice, and 'grows' these pearls in a series of steps: extraction of citations and references from the initial pearls; identification of further pearls from cited and referenced papers; repetition of citation and reference searches; and manual search of references. This process is repeated until no further papers of relevance are identified. On this basis, 76 relevant papers were identified and are referred to, when relevant, in this chapter.

This chapter is organised as follows. The next section considers, at a conceptual level, what the cost-effectiveness threshold to inform NHS decisions, such as those made by NICE's advisory committees, should represent. *Estimating the threshold* considers alternative routes to generating an empirical estimate of such a threshold. The final section provides a brief overview of the methods used in the study.

What should the National Institute for Health and Care Excellence threshold represent?

The threshold as a measure of opportunity cost

The National Institute for Health and Care Excellence uses cost-effectiveness analysis (CEA) to inform the decisions underlying most types of guidance that it publishes. The use of CEA is most prominent in appraisals relating to new medicines,[3] but is also a key input into diagnostics appraisals as well as clinical guidelines and public health guidance.[3,5] For those interventions and programmes which impose additional costs on the NHS budget, their ICERs indicate the incremental cost per additional QALY achieved relative to appropriate comparators. Although the ICER is one of a number of evidential inputs into NICE committees' decisions, is has been shown to be the most important, at least for technology appraisals.[6]

Interpreting whether or not a given ICER is acceptable requires the use of a cost-effectiveness threshold. Given that NICE has no influence on the level of the NHS budget, its decisions need to consider that budget as a fixed constraint.[1] Therefore, the threshold should reflect the opportunity costs, in terms of health forgone, resulting from the imposition of additional costs on the NHS. When NICE issues positive guidance for a new intervention which imposes additional costs on the system, the resources required to deliver it must be found by disinvesting from other interventions and services elsewhere.[7] This displacement of existing services will result in health decrements for other types of individual.[8] Thus, the threshold represents the additional cost that has to be imposed on the system to forgo 1 QALY's worth of health through displacement.

Resource allocation decisions based on comparing an ICER with a cost-effectiveness threshold uses some simplifying assumptions, including those of constant returns to scale and perfect divisibility of programmes.[9] Some have suggested that this makes these methods unreliable,[10] although it has also been

argued that they provide useful approximations to guide decisions.[11] This report takes NICE's use of these methods as a starting point, and does not review the literature relating to this debate in any depth.

As *Figure 1* illustrates, CEA effectively becomes an analysis of net health benefits (NHBs): does the health gain from the new intervention outweigh the health decrements associated with the displacement of existing services necessary to fund it? *Figure 1* shows the incremental costs and QALYs associated with a new intervention relative to a comparator (the latter being shown at the origin). The new intervention generates 2 additional QALYs per patient and, at price P1, imposes an additional £20,000 per patient; the ICER is, therefore, £10,000 per QALY gained. At a threshold of £20,000 per QALY, the additional cost of £20,000 per patient translates into a decrement of 1 QALY (the distance between the *y*-axis and the threshold). This is because the threshold indicates the additional cost that needs to be imposed on the NHS budget in order to displace services that result in 1 QALY being forgone. Therefore, at that price, there is a net health gain of 1 QALY per patient (2 gained from the new intervention and 1 forgone through displacement). At a price of P2, the additional cost per patient of the new intervention is £40,000 and the net health gain is 0: the 2 additional QALYs from the new intervention are the same as the QALYs forgone through displacement. At the highest price of P3, the adoption of the new intervention would actually result in a net health decrement of 1 QALY as it generates fewer QALYs (2) than are forgone (3).

The use of the threshold to facilitate this NHB analysis can be expressed as in *Equation 1*:

$$NHB = \Delta h - \frac{\Delta C_h}{k} \tag{1}$$

where Δh is the change in health generated by the new intervention, ΔC_h is the additional health-care cost imposed on the NHS, and k is the cost-effectiveness threshold. The net health gain from adopting the new intervention is therefore the health gained, Δh, minus the health forgone, $\frac{\Delta C_h}{k}$.

Understanding the NICE cost-effectiveness threshold as representing opportunity costs in terms of health is explicit in NICE documentation (e.g. the *Guide to the Methods for Technology Appraisal*[3]). It is also clear in reports published by the Department of Health, such as the consultation report on value-based pricing.[4,12,13]

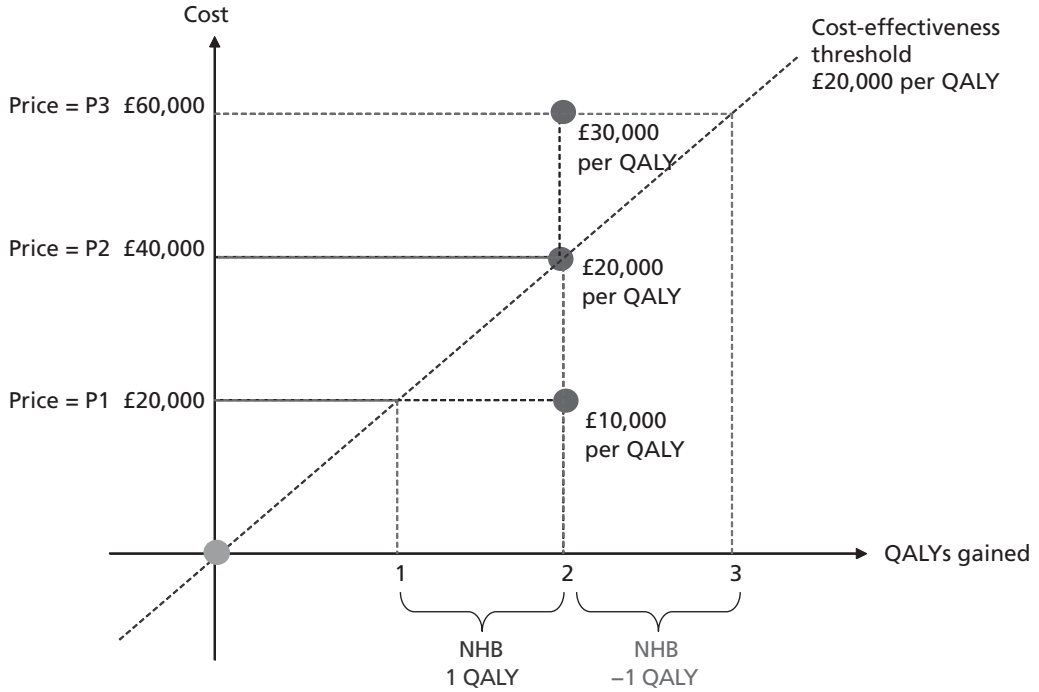

FIGURE 1 Graph showing illustration of the NICE threshold as a basis for assessing NHB. Reproduced from Value based pricing for NHS drugs: an opportunity not to be missed?, Claxton K, *et al.*, vol. 336, pp. 251–4, 2008 with permission from BMJ Publishing Group Ltd.

This conceptualisation of the principles of the NICE threshold is also described in the broader literature.[1,2] Formally, the threshold can be seen as the shadow price of the budget constraint.[1,2,8,14–16] Although this project focused on the use and estimation of a cost-effectiveness threshold for NICE decisions, the methods and estimates relate to any resource allocation decision within the NHS where the opportunity cost could fall anywhere in the system. Hence it could apply, for example, to Department of Health targets or to NHS England directives, as well as NICE guidance.

The threshold as the consumption value of health

Another view of what the threshold used in CEA should represent exists in the literature; however, in general terms this is based on the rate at which individuals are willing to forgo other forms of consumption to achieve health improvement [sometimes referred to as 'willingness to pay' (WTP)].[17–36] Although this consumption value of health can provide information on the value of health improvement and may guide decisions such as the level of the overall NHS budget, it does not inform decisions regarding how to allocate a fixed budget within the health-care system.

The reason for this is that the consumption value of health applies equally to health gained as well as to health forgone. This is shown in *Equation 2* where the consumption value of health, *v*, is added to the definition of NHB in *Equation 1*. This simply involves valuing both health gained and health forgone by the same consumption value of a unit of health, *v*. Therefore, the use of the consumption value is irrelevant: a treatment considered cost-effective in *Equation 1* (i.e. to have a positive NHB) will inevitably be considered cost-effective in *Equation 2*, and an intervention with negative NHB (i.e. not cost-effective) will remain as such in *Equation 2*.[a] Therefore, the magnitude of the threshold, *k*, is not a value judgment but an empirical question which can, in principle, be estimated.

$$NHB = v.\Delta h - \frac{v}{k}\Delta C_h \qquad (2)$$

Estimating the threshold

The National Institute for Health and Care Excellence's threshold range

The National Institute for Health and Care Excellence has been reluctant to specify a single cost-effectiveness threshold used in its decision-making.[6] It has also consistently emphasised that factors other than CEA are taken into consideration by the various advisory committees.[3,5,6,38–40] Therefore, it has preferred to indicate the range within which its threshold value lies (i.e. £20,000–30,000 per QALY gained).[3,5] Alongside this, it has provided an indication of the role other factors play in determining which point of threshold range is relevant. The latest guide[3] suggests that an ICER < £20,000 is likely to lead to recommendation unless the evidence is considered highly uncertain; an ICER between £20,000 and £30,000 will lead to recommendation if the committee is also happy with the levels of uncertainty in the evidence and/or the QALY does not capture all aspects of benefit; and an ICER > £30,000 would be recommended only if issues related to levels of evidential uncertainty and a failure to capture all benefits in the QALY are particularly compelling.

In 2009, NICE issued further supplementary guidance relating to the appraisal of interventions for patients with short life expectancy (LE), although this can be considered to relate more to the measure of benefit than factors to be considered outside of cost-effectiveness.[41] In 2012 NICE issued a draft update of its methods guide which added that, if a new technology has an ICER > £20,000 per QALY, the committee's deliberations would also consider 'aspects that relate to non-health objectives of the NHS' (e.g. wider social considerations and/or costs that fall outside the NHS budget).[42]

Although NICE has carefully argued the case for why its decisions are not driven entirely by a comparison of the ICER with its threshold range, it has not provided any empirical evidence for why the threshold range takes the value it does. Indeed it has been widely argued than an empirical basis for these values should be generated.[4,43–47] For example, the House of Commons Health Select Committee in 2008 argued:

> *The affordability of NICE guidance and the threshold it uses to decide whether a treatment is cost-effective is of serious concern. The threshold is not based on empirical research and is not directly related to the budget, it seems to be higher than the threshold used by [primary care trusts] PCTs for treatments not assessed by NICE. Some witnesses, including patient organisations and pharmaceutical companies, thought that NICE should be more generous in the cost per QALY threshold it uses, and should approve more products. On the other hand, some PCTs struggle to implement NICE guidance at the current threshold and other witnesses argued that a lower threshold should be used. We recommend that the threshold used by NICE in its full assessments be reviewed; further research comparing thresholds used by PCTs and those used by NICE should be undertaken . . .*
>
> *p. 6*[4]

The basis for empirical work

Although there is acceptance of the need for empirical work on the NICE cost-effectiveness threshold, a set of issues exists regarding the starting point for such analysis. One aspect of this is the view that the nature of the services that are displaced in response to additional costs being imposed by NICE guidance, and hence the magnitude of the health forgone for other patients, will depend on the productivity of the NHS and its overall (inflation-adjusted) budget, both of which have increased since NICE initially defined its threshold range.[48,49] In principle an increase in the (real) NHS budget would allow it to introduce interventions which were previously not cost-effective which might be expected to increase the threshold if these interventions were the marginal ones displaced in response to the budget impacts of NICE recommendations. However, any increase in the NHS budget may be allocated to non-discretionary expenditure. This would include, for example, expenditure relating to national initiatives such as new contracts for consultants and activities to meet waiting list targets as well as, of course, the implementation of NICE guidance. The non-discretionary nature of such expenditure means that these types of activities cannot easily be disinvested from given a need to release resources to fund NICE guidance. Therefore, if an increase in the NHS budget is largely devoted to these types of non-discretionary expenditure, there will be a limited impact on the threshold.

Gains in productivity may come through doing worthwhile activities more cost-effectively, including for those marginal interventions displaced by NICE recommendations, suggesting a reduction in the threshold. Alternatively, productivity gains might come through discontinuing activities which are not worth doing (i.e. that produce no health improvement), freeing resources for additional cost-effective interventions which may be the marginal services displaced by NICE guidance – this can have the result of increasing the threshold.

The net effect of these changes on the threshold could not be determined a priori and would depend on how any additional (real) budgets were allocated and how the gains in productivity where achieved. This does emphasise the fact that the threshold may change over time in response to these and other broader developments, and this would have to be considered as part of any regular updating of the empirical analysis of the threshold.

A second issue to be considered relates to how decisions are taken locally about any displacement following NICE guidance. The principles of CEA suggest that such displacement should relate to interventions which are the least cost-effective of those currently covered by the budget.[14] The basis for how local commissioners and providers make their disinvestment decisions is not clear, however, and there have been calls for greater transparency and guidance in this area.[48] It would be entirely unrealistic to assume that displacement only takes place in those existing services which are the least cost-effective. The reality is that numerous criteria are likely to be used by commissioners in implementing disinvestment,

and that significant variation will exist between local decision-makers.[8] Such criteria might include, for example, equity concerns about a particular disadvantaged group locally or capacity constraints regarding particular services. Therefore NICE needs to know what is likely to happen on average across the NHS given the reality of local decisions. If local decision-making changes over time – for example, if local commissioners become more focussed on displacing services which are the least cost-effective, in terms of population health – this may affect the estimate of the threshold.

Studying displacement locally

A reasonable conclusion from a consideration of these issues is, therefore, that local decisions about disinvestment are likely to be an important determinant of the NICE threshold.[50–55] Appleby *et al.*[56] sought to assess whether or not it was possible to study local decisions about service investment and disinvestment to infer the cost-effectiveness thresholds being used (implicitly) locally and to draw conclusions about the appropriate level of the NICE threshold. They identified six PCTs and undertook structured interviews with each of the directors of public health. They also administrated questionnaires to an opportunistic sample of finance directors from NHS trusts. On this basis they developed a list of new services as well as those that had been deferred or discontinued. An attempt was made to estimate the implicit local ICER relating to these decisions by using any cost-effectiveness evidence used to inform the decisions together with relevant evidence on cost-effectiveness from the published literature.

The study found it quite straightforward to identify specific services that had been introduced, discontinued or deferred, but concluded that these decisions were typically based on clinical and other non-economic factors. A number of 'decisions at the margin' were identified but none of these were based on CEA. Instead, the basis for changes in services was a 'business case', or overall cost impact. It was possible to impute cost-effectiveness for most of the services affected, but the study concluded that, even with a larger sample of commissioners and providers, it would be very difficult to estimate an implied cost-effectiveness threshold locally. This would be because, first, most PCT decisions were service reconfigurations including demand management and waiting list initiatives. By their nature, teasing out the incremental cost and health effects, potentially across numerous types of patients, would be an enormous challenge. Second, there would be difficulty in identifying all local decisions as many options for investment, deferment or discontinuation are rejected before they are made more explicit in documentation. A third problem would be the finding that a range of criteria is used to make local decisions, with relatively little concern for cost-effectiveness, making a local threshold estimated in this way hard to interpret. A final challenge would be that it would be very difficult to establish a causal link between a change in local NHS budget and specific local investment and disinvestment decisions. The Appleby *et al.*[56] study highlights the problems that exist in deriving a cost-effectiveness threshold from a bespoke study of specific local resource allocation decisions.

What evidence is needed?

Given the challenges of studying local decisions as a means of establishing the NICE threshold, and keeping in mind NICE's remit, it is possible to suggest a series of important characteristics that estimation methods should have from the perspective of principle and practice:

- They should reflect the effect of NICE guidance on the *average* of the displacement decisions taken across the NHS, with less consideration on which types of patients and interventions are affected and why the decisions are taken. NICE cannot be expected to reflect what is likely to be marked variation between local commissioners and providers in how they react to an effective reduction in their budget as a result of positive guidance. Given NICE's remit, it is the expected health effects (in terms of length and QoL) of the average displacement within the current NHS (given existing budgets, productivity and the quality of local decisions) that is relevant to the estimate of the threshold.
- The methods used should not be a 'once and for all' effort but should facilitate regular updates to reflect changes in the broader NHS context such as changes in the overall real budget and productivity. This requires the use of data sources that are currently routinely available, are expected to become so

in the future or could be made available at reasonable cost. It may be possible to glean some idea of how the threshold may change in the future by studying how it has changed in the past, which would require routine data sources to extend back over a period of time. Periodic updating using explicit scientific methods would encourage accountability through scrutiny of estimates by relevant stakeholders. It would also provide more predictability in likely changes to the threshold for the investment decisions of technology manufacturers.

- The nature of the displacement of existing services (and hence the magnitude of the health forgone) will depend on the scale of the budget impact coming through NICE guidance. Therefore, the methods used to estimate the threshold should ideally be able to reflect this budget impact.
- The methods should recognise the inevitable uncertainty relating to the evidence currently available for threshold estimation and translate this into an expression of the uncertainty in the estimate of the threshold. As well as providing information with which NICE can determine the appropriate implications for its choice of a threshold value, this consideration of uncertainty can help to prioritise further research or the collection of routine data.

An introduction to study methods

The current study has sought to develop methods consistent with these desired characteristics. This section provides a summary of the methods used. Further details are provided in each of the later chapters relating to the various components of work, and in the associated appendices. The general approach taken is to use routinely available data to look at the relationship between overall NHS expenditure and patients' health outcomes. By exploiting differences between PCTs in expenditure and outcomes, it is possible to infer the costs of generating health improvement from NHS services at the margin. In principle, this is what is needed as the basis of the NICE cost-effectiveness threshold as it provides an indication of the health forgone through the services displaced by the additional budget effect of the Institute's guidance.

Past work

The study was able to build on some key existing research relating to the relationship between NHS expenditure and mortality.[57–59] Since 2003 data on expenditure on health care across 23 programme budget categories (PBCs) of care have been available for each PCT in the NHS in England. These PB data seek to allocate, to broad areas of illness according to the primary diagnosis [using *International Classification of Diseases*, Tenth Edition (ICD-10) codes], all items of NHS expenditure, including expenditure on inpatient care, outpatient care, community care, primary care, and pharmaceuticals and devices.

For the purposes of this study, the merit of these data is that they open up the possibility of examining the relationship between differences in local spending and associated disease-specific mortality outcomes routinely available from the National Centre for Health Outcomes Development. In each programme, the elasticity of outcome with respect to changes in expenditure was estimated controlling for differences between PCTs in need. Changes in mortality were then transformed into YLG using assumptions regarding LE without the change in expenditure. This provides estimates of the marginal cost per YLG on average across the NHS by PBC.

This work focused largely on spending and outcomes in two of the largest programmes: circulatory disease and cancer,[60] but has also informed the link across other programme categories.[58,61] Estimates of the cost per YLG for 2006/7 were £15,387 for cancer, £9974 for circulation problems, £5425 for respiratory problems, £21,538 for gastrointestinal problems and £26,428 for diabetes. These estimates were based on a straightforward, though carefully constructed, theoretical model of health production which informs the specification and estimation of a set of equations. These dealt with the challenge of there being alternative plausible directions of causation (e.g. between expenditure and health outcomes within a programme). This problem of endogeneity was addressed by identifying and testing suitable instrumental variables (IVs). In doing so, they accounted for variation in the clinical needs of the local

population relevant to each programme together with broader local environmental factors relevant to the costs of care and outcomes.

This earlier work provides a strong foundation for the current study through its consideration of the average marginal elasticity of outcome with respect to programme expenditure. However, to estimate the threshold suitable for NICE decision-making, a number of further elements of research are necessary, and these are described below.

Further econometric analysis

This further econometric research is covered in *Chapter 3*, with full details *in Appendix 2*. The earlier work estimated the cost per YLG for the major programme areas. The NICE threshold needs to relate to the whole NHS and will, therefore, depend on all the programmes of care where disinvestment takes place. Given that each programme of care has been estimated separately, it is not clear how expenditure on particular programmes changes with the overall budget. For example, does disinvestment tend to fall on respiratory care or diabetes following a budget impact from NICE guidance? Therefore, the current study has further developed the econometric analysis to reflect the need for PCTs to operate within a fixed overall budget. This provides an estimate of the 'budget elasticity of expenditure' in each PBC, and facilities estimates of the impact of marginal increases (or decreases) in overall PCT budgets on spending in each PBC.

As well as indicating budgetary influences on programme spending, these elasticities have then been linked to changes in mortality outcomes by programme. These changes are used to estimate years of life lost (YLL) taking account of the fact that some of the observed deaths would have occurred anyway (had the same population not been at risk in the particular PBC); that is, taking account of unobserved counterfactual deaths. This takes into account how such budgetary changes (such as those imposed by NICE guidance) translate through local decisions into changes in expenditure on programmes of care and then to health outcomes.

Changes in budgets are in practice incremental rather than marginal, and it may be the case that the outcome elasticities of programme expenditure in times of budgetary increase (when new initiatives are introduced) are not the same as in times of budgetary decrease (when the focus is on disinvestment). The possible effects of non-marginal changes have therefore been explored. The project has also sought to explore how both expenditure and outcome elasticities, and hence the threshold, vary over time, and this has been assessed by generating relevant estimates for three sets of data.

A development from earlier work has been to relate expenditure in period t to mortality in periods t, $t+1$ and $t+2$. Although the data used are largely cross-sectional, mortality data are linked so as to follow expenditures. Given the inevitable uncertainty relating to assumptions in the analysis, extensive sensitivity analysis is undertaken to consider the implications for the estimates.

Moving from life-years to quality-adjusted life-years gained

A key element of the research has been to take the results of the econometric work linking NHS spending and mortality, and to translate this into effects on life-years and QALYs. The methods planned for the study included a consideration of local data, collected routinely by PCTs, on the types of interventions in which local decision-makers were investing and disinvesting. The aim was to inform the link between the effects of expenditure changes on mortality and impacts on broader health in terms of QALYs. These data may have indicated the types of interventions and services, within a given PBC, on which investment and disinvestment were taking place. Using targeted literature reviews, estimates of QoL for those activities may have been identified. However, it was established that there were limited data available at a local level to facilitate this type of analysis, so other data sources were used for this purpose (see *Addendum 2: the role of data on local NHS decisions* in *Appendix 3*).

It has therefore been necessary to consider alternative data and approaches. This is tackled using three sequential steps:

i. translate the estimated effects on mortality from the econometrics work into life-years by exploring the limitations of the mortality data available at PCT level and the published YLL figures used in the econometric analysis, and by considering how to improve the estimates using additional data and analysis
ii. consider how estimates of life-year effects can be adjusted for the QoL in which they are lived, taking account of the gender and the age at which life-years are gained or lost as well as the QoL implications of particular diseases
iii. explore ways to take account of those effects on health not directly associated with mortality and life-year affects (i.e. the 'pure' QoL effects) to estimate an overall cost per QALY threshold.

This aspect of the analysis is described in *Chapter 4* with further details provided in *Appendix 3*.

The central or 'best' estimate is based on two assumptions relating to the health effects associated with expenditure, one conservative and the other more optimistic. The first assumption is that the health effects of changes in 1 year of expenditure are restricted to 1 year. This is implicit in the estimates of outcome elasticities estimated in the econometric analysis. This is likely to underestimate effects on mortality as expenditure that reduces mortality risk for an individual in 1 year may well also reduce their risk over subsequent years, and expenditure may also prevent disease in future patient populations. Therefore, total health effects will be underestimated and the cost per life-year or QALY threshold will be overestimated. Although undoubtedly conservative, it may be offset to some extent by the more optimistic assumption. It is assumed that any death averted by expenditure in 1 year will return the individual to the mortality risk of the general population, that is the years of life gained (YLG) associated with each death averted are based on what would have been their LE taking account of their of age and gender (using life tables for the general population).

The extreme upper and lower bounds for cost per life-year and cost per QALY thresholds are based on making both of these assumptions either optimistic (providing the lower bound for the threshold) or conservative (an upper bound for the threshold). The lower bound is based on assuming that health effects are not restricted to 1 year but apply to the remaining disease duration for the population at risk during the expenditure year. The upper bound is based on the combination of assuming that health effects are restricted to 1 year and that any death averted is only averted for the minimum duration consistent with the mortality data used to estimate the outcome. It is very important to note that the lower and upper bounds are very much extreme values with limited plausibility.

Conclusions

A cost-effectiveness threshold is needed to inform decisions by NICE, the NHS more generally or the Department of Health which reflects the fact that opportunity costs fall on services and population health at a local level. Given that it is (and will continue to be) unfeasible to know precisely which services are displaced across all localities within the NHS, the threshold should reflect the average implications on health of actual local decisions about marginal changes in local service caused by changes in expenditure. The absence of an empirical estimate of the threshold which reflects these principles lies behind the project. Using data routinely collected in the NHS or available data that could be routinely updated, the study is organised into two major parts. The first updates earlier analysis to estimate the relationship between NHS expenditure and mortality, and the second seeks to translate these mortality effects into the more general measure of health – the QALY.

Chapter 3 The link between NHS spending, mortality and the cost of a life-year

Introduction

This section presents an overview of the econometric work undertaken to estimate the link between NHS spending and mortality and how this is used to calculate the cost of a life-year. As well as providing the analytical foundations for estimates of cost per QALY threshold presented in *Chapters 4* and *5*, this work contributes to the ongoing debate about the extent to which additional health-care expenditure yields improved patient health outcomes.

The work presented in this report takes advantage of the availability of two new data sets to examine the relationship between NHS expenditure and mortality rates for various disease categories. One data set contains mortality rates for various disease categories at the level of geographically defined local health authorities, PCTs. The other data set presents NHS expenditure by PCT on 23 broad programmes of care (these programmes are listed in *Table 1*). This data set embraces most items of publicly funded expenditure, including inpatient, outpatient and community care, and pharmaceutical prescriptions. NHS revenue derives almost entirely from national taxation, and access to the system is generally free to the patient. The system is organised geographically, with responsibility for the local administration of the NHS devolved to PCTs.[a] PCTs are allocated fixed annual budgets by the Department of Health, within which they are expected to manage the health care in the locality.

We employ a model that assumes that each PCT receives an annual financial lump sum budget and allocates its resources across the 23 programmes of care to maximize the health benefits associated with that expenditure. Estimation of this model using the expenditure and mortality data facilitates two related studies: first, a study of how changes in the NHS budget impact on expenditure in each care programme; and second, a study of the link between expenditure in a programme and the health outcomes achieved, notably in the form of disease-specific mortality rates. The latter also permits the calculation of the cost of an additional life-year for individual programmes of expenditure.

The work presented here draws heavily on previous studies using these data[57,59,60,62,63] and innovates in four major ways: (1) we relate expenditure in time period t to outcomes in periods t, $t+1$, and $t+2$ combined;[b] (2) we present plausible outcome models for a large number of budgeting categories – previous studies have tended to focus on the four largest care programmes; (3) we present estimates of the cost of a life-year for the enlarged number of programmes and, importantly, with the aid of assumptions about the productivity of programmes without a meaningful mortality-based outcome indicator, we extend our individual programme estimates to incorporate expenditure across all programmes of care; and (4) although the models we present appear well specified according to appropriate statistical tests, we subject our results to a substantial sensitivity analysis.

The next section presents a brief review of the relevant literature on which the study builds. This is followed by a summary overview of our approach to estimating the cost per life-year across the various programmes of care and the results obtained using PB data provided by the Department of Health. Further details of all aspects of the modelling approach, description of the data, the results we derive and calculation of costs per life-year are set out in *Appendix 2*. This section is intended to be supported by the information contained within *Appendix 2*.

TABLE 1 National (all PCT) expenditure per head (£) and growth in expenditure (%) by PBC group, 2003/4–2008/9

PBC		Spend (£) per head 2003/4	Spend (£) per head 2004/5	Spend (£) per head 2005/6	Spend (£) per head 2006/7	Spend (£) per head 2007/8	Spend (£) per head 2008/9	Growth (%) 2004/5	Growth (%) 2005/6	Growth (%) 2006/7	Growth (%) 2007/8	Growth (%) 2008/9	Share of total spend (%) 2004/5	Share of total spend (%) 2008/9
1	Infectious diseases	17.95	20.22	23.61	20.88	22.08	23.46	13	17	–12	6	6	1.7	1.5
2	Cancers and tumours	64.95	75.54	83.24	81.67	90.21	94.55	16	10	–2	10	5	6.3	6.2
3	Blood disorders	14.08	17.00	17.48	16.58	19.44	19.50	21	3	–5	17	0	1.4	1.3
4	Endocrine, nutritional	28.96	31.86	37.26	36.70	39.39	43.38	10	17	–1	7	10	2.7	2.8
5	Mental health	133.31	146.83	158.95	166.53	180.90	191.21	10	8	5	9	6	12.2	12.5
6	Learning disability	37.93	43.37	46.54	48.36	54.20	56.11	14	7	4	12	4	3.6	3.7
7	Neurological	29.83	35.09	41.06	55.27	62.43	67.64	18	17	35	13	8	2.9	4.4
8	Vision problems	24.61	27.65	28.24	26.97	30.69	32.95	12	2	–4	14	7	2.3	2.2
9	Hearing problems	5.73	6.32	6.27	6.21	8.07	8.16	10	–1	–1	30	1	0.5	0.5
10	Circulatory disease	110.12	122.37	124.28	122.06	124.77	129.94	11	2	–2	2	4	10.2	8.5
11	Respiratory system	54.60	62.71	69.56	65.07	67.68	77.97	15	11	–6	4	15	5.2	5.1
12	Dental problems	10.78	13.55	24.91	51.93	59.45	62.44	26	84	108	14	5	1.1	4.1
13	Gastrointestinal system	63.56	73.22	81.30	73.30	75.05	77.89	15	11	–10	2	4	6.1	5.1
14	Skin problems	20.98	24.90	26.84	28.31	30.41	32.34	19	8	5	7	6	2.1	2.1
15	Musculoskeletal system	61.36	71.72	74.74	66.75	75.91	79.68	17	4	–11	14	5	6.0	5.2
16	Trauma and injuries	62.31	72.13	76.41	57.29	57.56	63.54	16	6	–25	0	10	6.0	4.2
17	Genitourinary system	55.32	62.38	67.38	68.98	67.83	73.78	13	8	2	–2	9	5.2	4.8

PBC		Spend (£) per head 2003/4	Spend (£) per head 2004/5	Spend (£) per head 2005/6	Spend (£) per head 2006/7	Spend (£) per head 2007/8	Spend (£) per head 2008/9	Growth (%) 2004/5	Growth (%) 2005/6	Growth (%) 2006/7	Growth (%) 2007/8	Growth (%) 2008/9	Share of total spend (%) 2004/5	Share of total spend (%) 2008/9
18	Maternity	52.28	55.04	60.42	57.64	57.09	60.44	5	10	–5	–1	6	4.6	3.9
19	Neonate conditions	11.72	13.93	13.42	13.17	15.15	17.23	19	–4	–2	15	14	1.2	1.1
20	Poisoning	9.68	12.32	14.25	14.59	15.84	18.31	27	16	2	9	16	1.0	1.2
21	Healthy individuals	20.29	22.77	26.18	26.85	31.44	35.74	12	15	3	17	14	1.9	2.3
22	Social care needs	24.81	30.93	33.59	30.29	35.29	36.58	25	9	–10	17	4	2.6	2.4
23	Other (includes GMS/PMS)	136.94	157.75	171.82	209.70	232.02	227.71	15	9	22	11	–2	13.2	14.9
1–23	All PBCs	1052.12	1199.60	1307.76	1345.10	1452.91	1530.59	14	9	3	8	5		

GMS, general medical services; PMS, primary medical services.
The population figures for 2003/4, 2004/5 and 2005/6 are identical (the total for England is 49,175,998).
The corresponding figure for 2006/7 is 50,476,231, for 2007/8 it is 50,695,989 and for 2008/9 it is 51,220,531.
The spend per head figures are calculated by summing expenditure across all PCTs and dividing by the national population.
All figures are at current prices.

Previous studies

One of the most fundamental yet unresolved issues in health policy is the extent to which additional health-care expenditure yields patient benefits, in the form of improved health outcomes. The work of health technology agencies such as NICE has greatly improved our understanding at the micro level of the costs and benefits of individual technologies. However, there remains a dearth of reliable evidence at the macro level on the benefits of increased health system expenditure.

The empirical problems of estimating the link between spending and health outcomes are manifest. If one relies on a time series of health outcome data for an individual health system it is difficult to disentangle the impact of expenditure from a wide range of other temporal influences on health, such as technological advances, epidemiological changes, and variations in broader economic circumstances. Similar methodological difficulties arise if one attempts a cross-sectional comparison of different health systems. In particular, when seeking to draw inferences from international comparisons, researchers might have failed to adjust for all the potential external influences on health outcomes and this might account in part for their findings. For example, in an early cross-sectional study of 18 developed countries, Cochrane *et al.*[64] use regression analysis to examine the statistical relationship between mortality rates on the one hand and per capita gross national product (GNP) and per capita consumption of inputs such as health-care provision on the other. They found that the indicators of health-care provision were generally not associated with outcomes in the form of mortality rates. Thereafter, the failure to identify strong and consistent relationships between health-care expenditure and health outcomes (after controlling for other factors) has become a consistent theme in the literature, whereas, in contrast, socioeconomic factors are often found to be good determinants of health outcomes.[65–67]

There is furthermore the possibility that indicators of health system inputs, such as expenditure, are endogenous, in the sense that they have to some extent been influenced by the levels of health outcome achieved. In addition, the difficulty of satisfactorily estimating the impact of health system inputs on outcomes is compounded by the great heterogeneity of health care, the multiple influences on outcomes, and the rather general nature of the outcome mortality measure traditionally used. Consequently, the failure to detect a significant positive relationship between expenditure and health outcome might reflect the difficulties associated with any such study rather than the absence of such a relationship. For example, Gravelle and Backhouse[68] examine some of the methodological difficulties associated with empirical investigation of the determinants of mortality rates. These include simultaneous equation bias and the associated endogeneity problem (that the level of health-care input might reflect the level of health outcome achieved in the past), and that a lag may occur between expenditure and outcomes (studies typically assume that expenditure has an immediate effect on mortality).

To avoid the difficulties imposed by data heterogeneity inherent in international analyses, the study by Cremieux *et al.*[69] examines the relationship between expenditure and outcomes across 10 Canadian provinces over the 15-year period 1978–92. They find that lower health-care spending is associated with a significant increase in infant mortality and a decrease in LE. Although challenging the received empirical wisdom, one difficulty with the Cremieux *et al.*[69] study is that the estimated regression equation consists of a mixture of potentially endogenous variables (such as the number of physicians, health spending, alcohol and tobacco consumption, expenditure on meat and fat) and exogenous variables (such as income and population density). The authors' chosen estimation technique (generalised least squared; GLS) does not allow for this endogeneity and consequently the coefficients on the endogenous variables may be biased.[68] Similarly, Nixon and Ulmann's study,[70] which uses three health outcome measures and various explanatory variables (such as per capita health expenditure) for 15 European Union (EU) countries over the period 1980–95, does not allow for the possibility that some of the explanatory variables may be endogenous.

More recently, studies have started to address the endogeneity issue.[71,72] Bokhari *et al.*[71] estimate a cross-section model for 127 countries using data for 2000. They employ two health outcome indicators (the under-5 mortality rate and the maternal mortality rate). Bokhari *et al.*[71] allow for the endogeneity of

health expenditure via the use of IV techniques, and they estimate the elasticity of these indicators with respect to total government health expenditure conditional on the level of education and basic infrastructure (such as road transport and sanitation). They find that health expenditure has a statistically significant negative impact on both under-five mortality and maternal mortality. The authors do note, however, that their focus on child and maternal mortality implicitly assumes that these outcome indicators are in some way representative of outcomes across all activities financed by government health-care expenditure. Data permitting, it would be preferable to relate health-care expenditure on under-fives to under-five mortality, and expenditure on maternal care to maternal mortality.

In this study we relate expenditure in a specific disease area to mortality associated with those diseases. We also address the endogeneity issue through the use of IVs and, unlike previous studies; we examine the sensitivity of our results to questions of instrument validity. Moreover, although previous empirical work has been loosely based on the notion of a health production function, it has rarely been informed by an explicit theoretical model. This is understandable, as the processes giving rise to the observed health outcome are likely to be very complex, and any theoretical model might become rather unwieldy. However, this absence of atheoretical model has sometimes led to atheoretical search for measures of health inputs demonstrating a statistically 'significant' association with health outcomes. In contrast, in this study we inform our empirical modelling with a theoretical framework. We believe that this may lead to a more convincing and better specified model of health outcomes than that used in many previous studies, and this model is outlined in the next section.

Modelling framework

In the literature on the relationship between health expenditure and health outcomes, the statistical model estimated often contains a mixture of exogenous variables (such as income and population density) and endogenous variables (such as health spending, the number of doctors, and spending on cigarettes and alcohol). In such circumstances, the application of ordinary least squares will lead to biased coefficients on the endogenous variables. To avoid this problem, Gravelle and Backhouse[68] recommend that analysts model, even if only informally, the decision-making process which generates the observed data set.

To avoid the problem of simultaneous equation bias we have constructed a very basic model of the budgeting and outcomes data generation processes. In places, the model makes some heroic assumptions (which we hope to relax in future work) but the framework reveals some of the more salient features of the data generation processes.

We assume – quite realistically – that each PCT, i, receives an annual financial lump sum allocation, y_i, from the Department of Health and that total within year expenditure for each PCT cannot exceed this amount. We also assume – less realistically – that this lump sum is allocated across the J programmes of care ($J = 23$) by a single decision-maker (although we know that in practice the programme budget data will in part reflect the myriad of individual clinical decisions that health-care professionals take every day and that these are decisions over which PCTs exercise little control).

We assume that each PCT adheres to a social welfare function, $W(.)$, that incorporates the health outcome (h) across all 23 programmes of care so that for each PCT:

$$W = W(h_1, h_2, \ldots, h_J). \tag{3}$$

Health outcomes might be measured in a variety of ways, but the most obvious is to consider some measure of improvement in LE, possibly adjusted for QoL, in the form of a QALY.

We assume that, for each PCT and for each programme of care, there is a 'health production function' that indicates the link between local spending on programme j (x_j) and health outcomes in the same programme (h_j). Two such production functions are illustrated in *Figure 2*. We assume that increased expenditure yields improvements in health outcomes, as expressed, for example, in local mortality rates, but at a diminishing rate. Clearly the shape of the curve might depend on the health needs of the local population (such as epidemiological conditions) and other local circumstances, such as socioeconomic conditions and local service input prices. Note that in *Figure 2* the cost of securing a given level of health outcome is – for whatever reason – higher in PCT_a than PCT_b.

In algebraic form, each PCT seeks to maximise total welfare across all J programmes of care ($J = 23$) subject to the health production function for each programme of care of the form:

$$h_j = f_j(x_j,\ n_j,\ z_j), \tag{4}$$

where n_j is the need for health care in programme j, x_j is PCT expenditure on programme j, and z_j represents environmental variables affecting the production of health outcomes in programme j [which might include private (non-PCT) health-care expenditure in the disease area]. Each PCT's problem is to select an expenditure level for each programme ((x_j^*)), so as to maximise the utility function in *Equation 3* subject to the health production functions in *Equation 4* and the budget constraint that total expenditure on all programmes should not exceed PCT income (y).

Algebraically, the budget constraint is:

$$x_1 + x_2 + \ldots + x_{23} \leq y \tag{5}$$

Solving this maximisation problem yields the result that the optimal level of PCT expenditure in each category, (x_j^*), is a function of the need for health care in each category ($n_1, n_2, \ldots, n_{23}$), environmental variables affecting the production of health outcomes in each category, ($z_1, z_2, \ldots, z_{23}$) and PCT income (y).

Thus:

$$\begin{aligned} x_1^* &= x_1(n_1, n_2 \ldots, n_{23}, z_1, z_2 \ldots, z_{23}, y) \\ x_2^* &= x_2(n_1, n_2 \ldots, n_{23}, z_1, z_2 \ldots, z_{23}, y) \\ x_{23}^* &= x_{23}(n_1, n_2 \ldots, n_{23}, z_1, z_2 \ldots, z_{23}, y) \end{aligned} \tag{6}$$

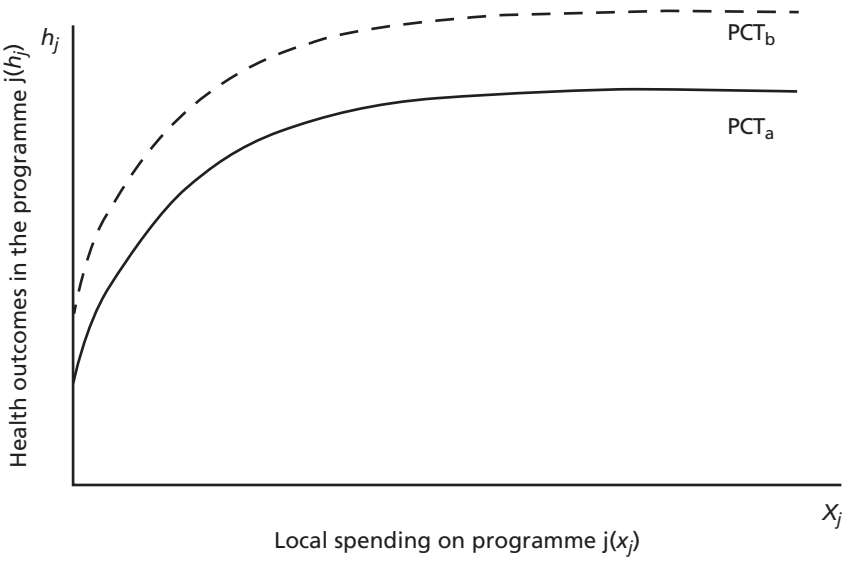

FIGURE 2 The health production function for programme j in two PCTs.

These results imply that each PCT will allocate expenditure across the 23 programmes of care so that the marginal utility of the last pound spent in each programme of care is the same. Of course, this does not mean that each programme receives the same amount of cash; financial allocations will depend on both the relationship between utility and outcomes, and on the relationship between outcomes and expenditure for each programme of care. If we assume that one extra unit of health outcome improves managerial utility by the same amount irrespective of the programme of care, then the decision-maker simply allocates expenditure across all programmes to maximise total health outcomes. This is achieved by ensuring that the marginal health outcome benefit (measured perhaps in QALYs) is the same for the last pound spent across all programmes of care.

Thus, for each programme of care, there exists an expenditure equation (see *Equation 6*) explaining the expenditure choice of PCTs and a health outcome equation (see *Equation 4*) which models the associated health outcomes achieved. As presented, our basic model is static in the sense that the health production function (see *Equation 4*) assumes that all health benefits occur contemporaneously with expenditure. We acknowledge that for some programmes of care benefits might occur ≥ 1 year after expenditure has occurred. This is particularly likely to be the case for those programmes aimed at encouraging healthy lifestyles, where some benefits may occur decades after the actual programme expenditure. For other programmes, such as maternity/reproductive conditions and neonate conditions, benefits may be largely contemporaneous with expenditure. However, although our data are largely cross-sectional in nature, we are able to link mortality data in such a way that this follows expenditures. Accordingly, for our empirical modelling we estimate models using expenditure for period t with mortality data for periods t, $t+1$, and $t+2$ combined. *Appendix 2* presents a number of sensitivity checks on these assumptions including models where mortality data precedes expenditure data[c] and shows that these results are fairly consistent with the results presented here.

Data

Programme budgeting in England

Prior to October 2006, there were 303 PCTs in England with an average population of about 160,000 people. In October 2006 the 303 PCTs became 152 PCTs. Some PCT boundaries remained unchanged while other PCTs were merged with one or more neighbours to form a new, larger, PCT. In a few cases the geographic area covered by an existing PCT was split between two or more new PCTs. These 152 PCTs have an average population of about 330,000 people. PCTs are allocated fixed annual budgets within which they are expected to meet expenditure on most aspects of health care, including inpatient, outpatient and community care, primary care and pharmaceutical prescriptions.

Programme budgeting data collection was initiated by the Department of Health in April 2003 when each PCT was required to prepare expenditure data disaggregated according to 23 programmes of health care. These programmes are defined by reference to ICD-10 codes at the four digit level, and most PBCs reflect ICD-10 chapter headings (e.g. cancer and tumours, circulation problems, renal problems, neonates, problems associated with the skin, problems associated with vision, problems associated with hearing, etc.). In some cases the 23 categories are broken down into further subareas to achieve a closer match with the various National Service Frameworks (NSFs); for example, the large mental health category is broken down into 'substance abuse', 'dementia', and 'other'.

Programme budgeting seeks to allocate all types of PCT expenditure to the various PBCs, including secondary care, community care and prescribing. However, the system acknowledges that a medical model of care may not always be appropriate, and two specific non-clinical groups – 'healthy individuals' and 'social care needs' – have been created. These are intended to capture the costs of disease-prevention programmes and the costs of services that support individuals with social rather than health-care needs. In addition, in some cases it is not possible to assign activity by medical condition, preventative activity, or social care need and, in these cases, expenditure is assigned to a residual category (PBC 23) entitled

'other'. The most important element of this residual programme is expenditure on general practitioner (GP) services (PBC 23a). In principle it should be possible to allocate each GP consultation to a particular care programme. However, at the moment the available data information systems do not permit such an allocation and so all primary care expenditure is allocated to this residual programme. The use of this residual category ensures that all expenditure is assigned to a programme of care.[73]

The aim of the programme budget classifications is to identify the entire volume of health-care resources assigned to broad areas of illness according to the primary diagnosis associated with an intervention. It serves a number of purposes, most notably to assist in the local planning of health care. However, for this study its crucial merit is that it opens up the possibility of examining the statistical relationship between local programme spending and the associated disease-specific outcome. Various forms of data collection and analysis are required to map PCT expenditure on acute, community and other services to the 23 PBCs. From the PCT perspective, however, the construction of each PCT's return largely involves collating information provided by other bodies and drawing on other information already in the PCT's own annual accounts. Details of how expenditure is assigned to programmes of care can be found in *Appendix 2, The collection of programme budgeting data*.

Table 1 shows the expenditure per head and the growth in this expenditure for each PBC for 2003/4–2008/9.[d] Year-on-year comparisons of expenditure in each group are complicated by the fact that the algorithms used to allocate activity to PBCs are regularly revised.[e] However, by 2008/9 total PCT expenditure per person had increased to £1531 (up 28% from 2004/5). The residual 'other' category (PBC 23) still accounted for the largest share of expenditure (14.9%) with per capita expenditure of almost £228, of which £145 was accounted for by primary care expenditure. Mental health (PBC 5) accounted for just over 12% of expenditure, but the expenditure share recorded by circulation problems (PBC 10) had fallen from 10.2% to 8.5%. Other categories recording a fall in budget share of more than a half of 1 percentage point included: the gastrointestinal system (down from 6.1% to 5.1%), the musculoskeletal system (down from 6.0% to 5.2%), trauma and injuries (down from 6.0% to 4.2%), and maternity (down from 4.6% to 3.9%). Categories recording an increase in budget share of more than a half of 1 percentage point included neurological problems (up from 2.9% to 4.4%) and dental problems (up from 1.1% to 4.1%).

Some of these changes will partly reflect revisions to the algorithms used to allocate expenditure to particular PBCs. For example in 2006/7 expenditure per person on musculoskeletal problems fell by 11% and expenditure on trauma and injuries fell by 25%. In the same year, expenditure on neurological problems increased by 35%. This suggests that some types of activity, which were previously allocated to musculoskeletal problems and/or trauma and injuries, were reallocated to neurological problems.

Similarly, up to and including 2006/7 expenditure that was not directly attributable to a particular programme category was apportioned using admitted patient care percentages.[f] In other words, if *x*% of total admitted patient care expenditure was allocated to PBC 1, then *x*% of all expenditure that was not directly attributable to a particular programme category was also allocated to PBC 1. With effect from 2007/8, however, NHS organisations were asked to select an appropriate basis for the apportionment of this non-programme-specific expenditure and that, where no reasonable basis existed, such expenditure was to be allocated to the 'other – miscellaneous' (PBC 23X) category. These two changes to the algorithm used to allocate expenditure to particular PBCs illustrate that year-on-year comparisons of expenditure need to be interpreted with care.

Expenditure per head on any given programme varies from one PCT to another and *Table 2* presents some statistics that indicate the degree of variation in expenditure levels across PCTs by PBC. Columns 3–6 of *Table 2* present descriptive statistics for PCT expenditure per person. These reveal that, for example, PCT per capita expenditure in the cancer programme averaged £96.30 across all PCTs, with the minimum spend being £62.90 and the maximum being £155.70.

TABLE 2 Primary care trust expenditure per head by PBC, 2008/9: (a) unadjusted; (b) adjusted for local costs; and (c) adjusted for local costs and local need

		Spend per head (unadjusted) (£)				Spend per head (cost adjusted) (£)				Spend per head (cost and need adjusted) (£)			
PBC		Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
1	Infectious diseases	26.5	24.6	8.6	151.8	25.7	21.7	8.6	136.7	25.0	21.4	9.5	139.5
2	Cancers and tumours	96.3	16.9	62.9	155.7	96.7	19.7	59.1	163.1	94.2	15.3	55.2	154.0
3	Blood disorders	20.3	7.0	7.7	49.4	20.2	6.5	8.0	49.1	19.7	6.0	8.2	44.2
4	Endocrine, nutritional	44.6	8.8	28.9	74.8	44.7	9.5	27.4	77.0	43.3	6.1	29.9	61.5
5	Mental health	201.4	60.0	118.9	474.1	200.3	54.0	122.8	422.8	194.0	41.9	132.3	362.0
6	Learning disability	56.8	18.8	7.7	125.9	57.0	19.4	6.8	123.6	55.7	18.8	6.7	136.6
7	Neurological	68.5	13.8	41.1	133.8	68.8	15.6	38.4	137.5	66.9	12.1	41.5	125.2
8	Vision problems	33.2	6.7	16.7	57.7	33.4	7.5	14.8	59.2	32.5	6.1	15.6	48.3
9	Hearing problems	8.6	3.7	0.9	24.0	8.7	3.9	0.9	25.5	8.3	3.3	0.8	22.0
10	Circulatory disease	131.6	26.7	88.0	317.3	132.2	30.5	78.2	327.6	128.5	24.4	75.7	326.9
11	Respiratory system	80.5	17.4	48.0	141.2	80.9	19.8	42.7	145.3	78.1	12.4	48.2	126.0
12	Dental problems	64.8	13.4	28.0	111.9	64.9	14.1	24.9	115.8	63.0	10.7	28.1	97.1
13	Gastrointestinal system	80.0	14.5	46.7	119.6	80.4	16.8	41.5	124.6	78.0	11.3	41.6	114.4
14	Skin problems	33.1	8.0	18.1	66.4	33.3	8.6	16.5	69.1	32.2	6.3	16.0	57.7
15	Musculoskeletal system	79.9	17.6	43.3	127.3	80.4	19.9	39.6	132.5	78.2	16.6	41.0	116.4

continued

TABLE 2 Primary care trust expenditure per head by PBC, 2008/9: (a) unadjusted; (b) adjusted for local costs; and (c) adjusted for local costs and local need (*continued*)

		Spend per head (unadjusted) (£)				Spend per head (cost adjusted) (£)				Spend per head (cost and need adjusted) (£)			
PBC		Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
16	Trauma and injuries	63.2	16.7	12.5	139.3	63.4	17.4	11.5	125.0	61.8	15.6	10.4	103.6
17	Genitourinary system	75.7	13.7	49.9	112.3	75.6	13.6	48.4	108.9	73.7	10.1	50.6	105.5
18	Maternity	63.3	16.7	24.6	124.4	63.1	15.8	21.9	117.9	61.4	12.8	24.4	96.5
19	Neonate conditions	18.4	7.3	6.4	46.4	18.2	6.8	6.6	43.7	17.8	6.6	5.8	47.8
20	Poisoning	18.6	4.2	10.8	31.2	18.7	4.7	9.6	32.3	18.2	3.9	10.1	33.1
21	Healthy individuals	38.4	18.1	9.7	125.0	38.4	17.8	8.9	115.6	36.7	14.5	9.4	104.5
22	Social care needs	40.8	56.6	0.1	415.2	41.2	59.2	0.1	432.9	39.7	55.0	0.0	411.5
23	Other (includes GMS/PMS)	230.8	44.5	138.2	396.1	230.2	42.4	140.7	356.5	226.8	45.8	134.1	346.0
All	All PBCs	1575.6	196.7	1225.7	2079.9	1576.3	217.3	1183.0	2173.1	1534.0	86.2	1390.1	1987.0

GMS, general medical services; max., maximum; min., minimum; PMS, primary medical services; SD, standard deviation.

Note

The above statistics relate to 152 PCTs and the mean expenditure figures will differ slightly from the national ones in *Table 1* because the statistics across PCTs are not weighted for the size of each PCT's population.

Some PCTs will be spending more than other PCTs simply because they face higher input costs. Columns 7–10 in *Table 2* present descriptive statistics for PCT per capita expenditure that has been adjusted for the unavoidable geographical variation in costs (input prices) faced by PCTs.[g] However, if anything, this adjustment appears to increase the variation in expenditure across PCTs; for example, the range of per capita expenditure on cancer increases from between £62.90 and £155.70 (unadjusted) to between £59.10 and £163.10 (adjusted for local health-care input prices).

Another cause of the variation in expenditure levels is the fact that the need for health care varies from one PCT to another. For example, areas with a relatively large proportion of elderly residents, or PCTs operating in relatively deprived locations, can be expected to experience relatively high levels of spending. The Department of Health has a well-developed methodology for estimating the relative health-care needs, which it uses as the basis for allocating health-care funds to PCTs.[75]

Columns 11–14 in *Table 2* present descriptive statistics for PCT per capita expenditure that has been adjusted for both the unavoidable geographical variation in costs and the local need for health care faced by PCTs.[h] For virtually every PBC, this adjustment reduces the variation in expenditure across PCTs; for example, the standard deviation of PCT per capita expenditure falls from £19.70 to £15.30 for the cancer programme. Although this adjustment reduces the variation in expenditure levels across PCTs, this decline is quite modest and there are still substantial differences in expenditure even after allowing for differences in local cost and need. For example, expenditure per head in the circulation problems category varies between £78 and £328 using cost-adjusted expenditure data, but falls between £76 and £327 using cost- and need-adjusted population data.

The variation in expenditure across PCTs has led some commentators to question the reliability of the PB data. The National Audit Office (NAO)[77] undertook a survey of trusts, PCTs and Strategic Health Authorities (SHAs) to assess the quality of the data. They concluded that although the processes for collecting the budgeting data were well defined in most areas, there remained scope for improvements to the robustness of some of the data (e.g. non-admitted patient care). Appleby *et al.*[78] also considered the issue of data reliability in variations in spending on cancer services and noted some large year-on-year changes. However, the authors point out that it is difficult to define what might be either an implausible level of expenditure or an implausibly large change in expenditure. This is complicated by the fact that the Department of Health makes regular improvements to the way in which activity is matched to programme categories.

As with most data sets, there are likely to be recording and other errors associated with the PB data. However, although we note that the allocation of PB data might not be perfect there is no systematic evidence of this. Accordingly, for each disease category, we observe that PCT expenditure per person varies considerably and this variation – holding constant input prices and the need for health care – offers the opportunity to examine whether or not PCTs that spend more on health care achieve a better outcome and, if so, at what cost. Empirical estimates of the strength of this relationship for several programmes of care are presented in this report.

Health outcome data

Most studies of the relationship between expenditure and outcome have used some measure of mortality as an indicator of the latter. We also employ mortality as an outcome measure. First, it is a relevant (albeit not comprehensive) measure of the outcome of health-care expenditure; and second, it is available for more disease areas than any other outcome measure at PCT level.

Although mortality is available (by PCT) for several disease areas, it is not available for just over a half of all programmes not least because it is simply not relevant for these programmes (e.g. for learning disabilities, vision problems, hearing problems, dental problems and skin problems). Moreover, even where a mortality measure is available, the ICD-10 coverage of the mortality data often falls short of the coverage of the expenditure data. For some programmes, therefore, we have combined the published mortality rates for

two or more disease areas in an attempt to match the ICD-10 coverage of the mortality data with that of the expenditure data.

Table 37 (see *Appendix 2*) shows how we have attempted to marry the mortality data (column C) and the expenditure data (column A). ICD-10 coverage of the component mortality rates for some PBCs falls short of the expenditure data and the extent of this shortfall is illustrated by the ratio reported in the final column of *Table 3*. For example, the cancers and tumours programme covers all expenditure associated with ICD-10 codes C00–C97 and D00–D49 but the PCT-based mortality data only relates to ICD-10 codes C00–C97. At the national (all England) level, figures are available which show that, in 2008, there were 62,072 deaths of those aged < 75 years from codes C00–C97 and that there were 63,076 deaths from codes C00–C97 and D00–D49 combined. In other words, the PCT-level mortality data reflect 98.4% of all deaths associated with the expenditure codes. We adjust our cost of life (year) estimates for this mismatch.

We acknowledge that mortality is a more relevant outcome indicator for some programmes (e.g. for circulatory problems) than for others (e.g. for epilepsy) and, for this reason, we would expect better results in some programmes than others. We also acknowledge that this focus on mortality ignores the impact of expenditure aimed at chronic care and at palliative care. Nevertheless, our focus on mortality is purely practical: it is both a widely available measure and clearly a relevant outcome indicator.[i]

The mortality data provide us with a number of possible outcome indicators including the < 75 years of age standardised mortality rate (SMR) and the (< 75 years) standardised years of life lost rate (SYLLR). The SMR gives equal weight to all deaths irrespective of the age at which they occur but the SYLLR gives greater weight to deaths that occur at earlier ages. For our purposes we focus on a measure of the avoidable YLL.[j] This is calculated by summing over ages 1–74 years the number of deaths at each age multiplied by the number of years of life remaining up to age 75 years. The crude YLL rate is simply the number of YLL divided by the resident population aged < 75 years. Like conventional mortality rates, the crude YLL rate can be age standardised to eliminate the effects of differences in population age structures between areas, and this (age) standardised YLL rate is the health outcome variable generally employed in this study.[79]

Other variables

We employ an IV estimation technique to our empirical models of the outcome and expenditure equations as described in the next section. This is due to (i) own programme expenditure is likely to be endogenous in the outcome equation and (ii) other programme need is likely to be endogenous in the own programme expenditure equation. Endogeneity of programme expenditure results from expenditure levels being responsive to levels of outcomes and/or unobserved need rendering expenditure correlated with the residuals in an ordinary least squared (OLS) regression of outcomes on expenditure. Due to limitations in the data available, need in the expenditure equation in the 'other' programmes is proxied by death rates (minus that due to the programme under investigation). This will be influenced by expenditure decisions, including expenditure in other programmes and is treated as endogenous in the expenditure model.

Instrumental variable estimation basically involves replacing the endogenous variable in the equation of interest with its predicted value from an OLS regression which regresses the endogenous variable on a set of IVs. These instruments should be good predictors of the endogenous variable (i.e. they should be relevant and strong predictors) but should be appropriately excluded from the equation of interest (i.e. they should be valid instruments).

We have a number of potential instruments available, mostly derived from the 2001 Population Census.[80] In our earlier studies we found that a small subset of these instruments proved sufficient to generate plausible results. These included the proportion of the population providing unpaid care; the proportion of households that are one pensioner households; index of multiple deprivation; and proportion of the population in the white ethnic group.

TABLE 3 Descriptive statistics for the instrumental and other variables[74]

Description	Observations	Mean	SD	Min.	Max.
Proportion of residents born outside the EU	151	0.0794	0.0876	0.0088	0.3817
Proportion of population in white ethnic group	151	0.8927	0.1299	0.3942	0.9926
Proportion of population of working age (16–74 years) with LLT	151	0.1182	0.0250	0.0709	0.1798
Proportion of population providing unpaid care	151	0.0990	0.0118	0.0662	0.1221
Proportion of population providing unpaid care (< 20 hours per week)	151	0.0667	0.0079	0.0461	0.0817
Proportion of population providing unpaid care (20–49 hours per week)	151	0.0113	0.0025	0.0065	0.0195
Proportion of population providing unpaid care (> 50 hours per week)	151	0.0210	0.0051	0.0093	0.0353
Proportion of population aged 16–74 years with no qualifications	151	0.2960	0.0642	0.1301	0.4555
Proportion of population aged 16–74 tears that are full-time students	151	0.0720	0.0270	0.0425	0.1626
Proportion of households without a car	151	0.2932	0.1046	0.1325	0.5761
Proportion of owner occupied households	151	0.6692	0.1128	0.2891	0.8205
Proportion of households in rented social (LA/HA) housing	151	0.2071	0.0918	0.0817	0.5356
Proportion of households in rented private housing	151	0.0924	0.0449	0.0349	0.2961
Proportion of lone pensioner households	151	0.1434	0.0184	0.0979	0.1942
Proportion of one parent households	151	0.0684	0.0180	0.0401	0.1207
Proportion of population aged 16–74 years that are permanently sick	151	0.0574	0.0213	0.0242	0.1215
Proportion of population aged 16–74 years that are long-term unemployed	151	0.0113	0.0052	0.0036	0.0287
Proportion of population aged 16–74 years in employment that are in agriculture	151	0.0117	0.0119	0.0016	0.0668
Proportion of those aged 16–74 years that are in professional occupations	151	0.2672	0.0688	0.1470	0.4958
IMD2007	151	23.8098	9.1168	8.0857	48.2627
Need index (incorporates CARAN formula)	151	1.0253	0.1334	0.7311	1.3479
MFF index for HCHS and prescribing	151	1.0021	0.0559	0.9410	1.1243
Diabetes prevalence rate 2007/8 (%, over 17 years)	151	5.4872	0.7982	3.2200	8.5100
Epilepsy prevalence rate 2007/8 (%, over 18 years)	151	0.7884	0.1489	0.4100	1.0900
HIV need index	151	1.1848	1.4984	0.1648	8.3332
Chronic kidney disease 2007/8 (%, over 18 years)	151	4.1687	1.2711	1.3500	8.4100
Maternity need index	151	1.0345	0.2106	0.6845	1.8129
Raw (unadjusted) population 2007/8	151	335,735	196,501	90,142	1,264,298

CARAN, Combining Age-Related and Additional Needs; HA, housing association; HIV, human immunodeficiency virus; IMD2007, Index of Multiple Deprivation 2007 data set; LA, local association; LLT, limited long-term illness; max., maximum; min., minimum; SD, standard deviation.

Note

These statistics are unweighted across PCTs and reflect the values for these variables as available for the regression analysis of PB expenditure data for 2007/8 and for 2008/9.

We also had available a further set of potential instruments and, where our more limited set of instruments failed to generate plausible results, we extended our instrument search to include this wider set of variables. This extended set of instruments is shown in *Table 3*.[k]

Our instruments reflect factors, such as socioeconomic deprivation and the availability of informal care in the community, which might indirectly impact on mortality rates and/or health-care expenditure levels. As we shall see, although our instruments 'pass' the appropriate statistical tests, some commentators claim that such tests may have 'low power' to detect the presence of invalid instruments. Consequently, in *Appendix 2, The sensitivity of the outcome elasticity to the validity of the instrument exclusion restrictions* we examine how sensitive our results are to the presence of invalid instruments.

Table 3 reports descriptive statistics for the socioeconomic and needs variables used in the study (these statistics are for the variables in absolute form). For example, on average, lone pensioner households comprise 14% of all households, the 'white ethnic' group accounts for 89% of the population and 10% of the population provide unpaid care.

In addition to the IVs, *Table 3* also reports descriptive statistics for the Department of Health's 'need for health care' index,[l] its need for human immunodeficiency virus (HIV) services index, and its need for maternity services index. The latter two indices are used to either supplement or replace the all service measure of need when estimating our models. The 'need for health care' index averages about 1 but varies substantially, with some PCTs having a needs index more than 25% below the national average and others facing a need for health care more than 30% above the national average. *Table 3* also reports descriptive statistics for some disease prevalence rates (e.g. for diabetes and for epilepsy) and, again, these are used to either supplement or replace the all service measure of need when estimating our models. Finally, the MFF index shows that input prices in the most expensive PCT are almost 20% above those in the least expensive PCT.

Approach to model estimation

The theoretical framework suggests the specification and estimation of a system of equations, with an expenditure and health outcome equation for each of the 23 programmes of care. However, this approach makes infeasible data demands, requiring variables to identify expenditure, need, environmental factors and health outcomes in each of the 23 programmes of care. Moreover, mortality rates are available for less than half of the 23 programmes. Rather than estimate a system of equations, we proceed on a programme-by-programme basis, estimating health outcome and expenditure equations for those programmes for which mortality data are available.

In line with the theoretical framework presented above, we specify the following expenditure (see *Equation 7*) and health outcome (see *Equation 8*) models for each of the 23 programmes of care. Accordingly, for the *j*-th programme of care we have:

$$x_i = \alpha + \beta n_i + \gamma m_i + \theta y_i + \varepsilon_i, i = 1, \ldots, 152 \tag{7}$$

$$h_i = \rho + \delta n_i + \pi x_i + \varepsilon_i, i = 1, \ldots, 152, \tag{8}$$

where x_i is expenditure; n_i is the own programme need for care; m_i is the need for care in other programmes; y_i is the total budget and h_i is the health gain in PCT i.

Ideally we should employ a programme-specific indicator of the level of need for each care programme (n_{ij}) but these are not readily available. When estimating both the outcome and expenditure models we therefore proxy the own programme health-care need using the 'needs' component of the

Department of Health's resource allocation formula.[m] This needs element is specifically designed to adjust PCT allocations for local health-care needs and accordingly, ceteris paribus, we would expect a positive relationship between expenditure and need for each programme of care. We would also expect a positive relationship between need and adverse health outcomes.[n]

The expenditure model includes both the own programme health-care need (which is proxied using the 'needs' component of the Department of Health's resource allocation formula) and the need for health care in all other programmes. In the absence of programme-specific measures of need, we use the 'all-cause mortality rate excluding the mortality rate in the programme of interest', m_i, as the proxy for need in other programmes of care.

All variables have been log-transformed so that parameter estimates can be interpreted as elasticities. In other words, a regression coefficient of 0.5 implies that a 1% increase in the regressor is associated with a 0.5% increase in the dependent variable.

Instrumental variable estimation

Other programme need, m_i, in the expenditure *Equation 7* and expenditure, x_i, in the outcome *Equation 8* are both likely to be endogenous rendering OLS both biased and inconsistent. Endogeneity of programme expenditure results from expenditure levels being responsive to levels of outcomes and/or unobserved need. Other programme need in the expenditure equation is proxied by death rates which is influenced by expenditure decisions and hence is treated as endogenous. To deal with this endogeneity we employ IVs estimation and implement two-stage least squares (2SLS). Unlike OLS, IV is a consistent estimator in the presence of an endogenous regressor and, although in finite samples the IV estimator will be biased, with the bias (providing certain assumptions are met) being less than that associated with OLS.

For the health outcome equation, IV estimation can be viewed as finding variables (instruments) that are good predictors of programme expenditure but which are appropriately excluded from the outcome equation of interest (that is, from *Equation 8*) because they are not predictive of outcome. The assumption is that these instruments impact on health outcome through their impact on expenditure only, and that they do not have a direct effect on the outcome.[o]

Similarly, for the expenditure equation, IV estimation can be viewed as finding variables (instruments) that are good predictors of the proxy for other programme need (m_i) but which do not belong in the expenditure equation of interest (that is, *Equation 7*). The assumption is that these predictors impact on own programme expenditure only through their impact on other programme need and that they do not have a direct effect on own programme expenditure.

The outcome and expenditure equations for any given programme may contain different IVs because these instruments are trying to predict different variables (own programme expenditure and other programme mortality respectively). In addition, the instrument set for, say, the expenditure equation may vary across programmes because the other programme need variable will reflect need in a different basket of programmes for each expenditure equation.

We have a number of potential instruments available, mostly derived from the 2001 Population Census.[80] In previous studies, we have often found that a small subset (four) of these instruments often proved sufficient to generate plausible results. However, if plausible results were not obtainable with some combination of these four instruments, we employed an extended instrument set. Further details of the identification of suitable instruments for each model can be found in *Appendix 2, Re-estimation of poorly performing models with an extended instrument set*.

The available instruments reflect factors, such as socioeconomic deprivation and the availability of informal care in the community, which might indirectly impact on mortality rates and/or health-care expenditure levels. The set of instruments associated with each estimated equation was selected on both technical and

pragmatic grounds. From a pragmatic point of view, we require a parsimonious set of instruments that satisfy the necessary technical criteria. These are, first, that they have face validity, that is, that they are plausible determinants of the endogenous variable being instrumented, and second, that the instruments are both relevant and valid. The relevance of an instrument set refers to its ability to predict the endogenous variable of concern, whereas validity refers to the requirement that instruments should be uncorrelated with the error term in the equation of interest.

Should the instrument set be strong, relevant and valid, 2SLS will produce consistent estimates of the parameters of the reduced form models. We subject the instrument sets to tests for validity using the Sargan–Hansen test of over identifying restrictions. The joint null hypothesis is that the instruments are valid instruments (i.e. they are uncorrelated with the error term), and that the instruments are correctly excluded from the outcome equation of interest. A rejection of the null hypothesis casts doubt on the validity of the instruments. We test for instrument relevance using Shea's[81] partial R^2 measure; this reflects the correlation between the excluded instruments and the endogenous regressor. However, even where valid and relevant, a non-zero but small correlation between the set of instruments and the endogenous regressors can lead to the problem of weak instruments, again rendering IV estimation biased. We test for the presence of weak instruments using the procedures set out in Stock and Yogo[82] and the Kleibergen–Paap Lagrange multiplier (LM) statistic. A general test of model specification is provided through the use of Ramsey's[83] reset test for OLS and an adapted version of the test for IVs.[84]

Finally, we check that the presumed endogenous variable is in fact endogenous using the test proposed by Durbin.[85] If the null hypothesis of exogeneity cannot be rejected, then we revert to using OLS. Although, in general, our instruments 'pass' the appropriate statistical tests, some commentators claim that such tests may have 'low power' to, and hence may fail, to reject the validity of the instruments when this is false in small samples. Consequently, in *Appendix 2, The sensitivity of the outcome elasticity to the validity of the instrument exclusion restrictions* we examine how sensitive our results are to the relaxation of the assumption that the instruments are valid.

Further details of our approach to IV estimation are set out in *Appendix 2*.

Results

The work presented here builds on previous studies of the link between expenditure and health outcomes. Martin *et al.*[60] reported outcome elasticities for two programmes (cancer and circulatory disease) using expenditure data for 2004/5 and pooled mortality data for 2002, 2003 and 2004.[p] This work was extended in a subsequent study[63] to include several other programmes and updated expenditure data (2005/6). However, the authors struggled to obtain sensible outcome models for some programmes of care. Attempts to improve model estimates by considering alternating measures of the population need for health care[q] and an extended set of potential IVs are presented in *Appendix 2, Analysis of programme budgeting expenditure for 2005/6 and mortality data for 2002/3/4*. This work forms the basis for the set of key results from the empirical modelling of health-care expenditures and outcomes using more contemporaneous data presented in the following sections. Details of all results presented are set out in *Appendix 2*.

2006/7 expenditure data and mortality data for 2006/7/8

This section presents results that relate expenditure in 2006 to mortality in the same year and in the 2 following years (i.e. in 2006, 2007 and 2008). Throughout our measure of the need for health care is derived from the Department of Health's resource allocation model based on the CARAN needs formula.[74] This represents a more up-to-date needs adjustment than the AREA based model[76] that has been applied in previous studies,[60,63] and is directly applicable to the 152 PCTs in existence in the 2006/7 expenditure year. Expenditure data has been adjusted for differences in input prices using the MFFs for HCHS and prescribing.[r] The outcome and expenditure results for the big four programmes are shown in *Table 4* with the relevant outcome and expenditure elasticities highlighted.

TABLE 4 Outcome and expenditure models for the big four programmes using spend data for 2006/7 (two MFFs) and mortality data for 2006/7/8

	(1) PBC 2, cancer	(2) PBC 2, cancer	(3) PBC 10, circulation	(4) PBC 10, circulation	(5) PBC 11, respiratory	(6) PBC 11, respiratory	(7) PBC 13, gastrointestinal	(8) PBC 13, gastrointestinal
Equation variable	Outcome model	Spend model	Outcome model	Spend model	Outcome model	Spend model	Outcome model	Spend model
Own programme spend per head	**–0.342*** **		**–1.434*** **		**–2.029*** **		**–1.536*** **	
	[0.099]		**[0.218]**		**[0.636]**		**[0.468]**	
Need (CARAN per head)	0.995***	1.626***	2.860***	2.306***	2.696***	1.449***	4.160***	2.040***
	[0.106]	[0.343]	[0.252]	[0.372]	[1.044]	[0.331]	[0.577]	[0.378]
Need (CARAN per head squared)	1.163***				2.451			
	[0.348]				[1.561]			
SYLLR (all deaths excluding cancer)		–0.855***						
		[0.191]						
PCT budget per head		**0.465**		**0.540***		**0.679*** **		**0.446***
		[0.300]		**[0.299]**		**[0.251]**		**[0.263]**
SYLLR (all deaths excluding circulatory)				–1.666***				
				[0.295]				
Permanently sick					0.759**			
					[0.367]			
SYLLR (all deaths excluding respiratory)						–0.672**		
						[0.305]		

continued

TABLE 4 Outcome and expenditure models for the big four programmes using spend data for 2006/7 (two MFFs) and mortality data for 2006/7/8 (*continued*)

	(1) PBC 2, cancer	(2) PBC 2, cancer	(3) PBC 10, circulation	(4) PBC 10, circulation	(5) PBC 11, respiratory	(6) PBC 11, respiratory	(7) PBC 13, gastrointestinal	(8) PBC 13, gastrointestinal
Equation variable	**Outcome model**	**Spend model**	**Outcome model**	**Spend model**	**Outcome model**	**Spend model**	**Outcome model**	**Spend model**
SYLLR (all deaths excluding gastrointestinal)								–1.206***
								[0.314]
Constant	6.501***	5.913***	11.413***	10.696***	13.756***	3.346	9.719***	8.370***
	[0.436]	[2.815]	[1.046]	[2.379]	[3.279]	[2.075]	[2.009]	[2.299]
Endogeneity test statistic	13.695	19.421	42.548	24.461	17.687	8.439	16.373	15.211
Endogeneity *p*-value	0.000215	1.05e-05	6.90e-11	7.58e-07	2.60e-05	0.00367	5.20e-05	9.61e-05
Hansen–Sargan test statistic	0.685	0.021	0.949	1.262	1.462	0.302	2.761	0.0164
Hansen–Sargan *p*-value	0.408	0.084	0.814	0.261	0.227	0.583	0.0966	0.0898
Shea's partial R^2	0.164	0.445	0.300	0.296	0.0785	0.327	0.140	0.356
Kleibergen–Paap LM test statistic	17.85	41.88	32.37	32.02	10.02	34.98	14.86	35.72
Kleibergen–Paap *p*-value	0.000133	8.04e-10	1.61e-06	1.11e-07	0.00666	2.54e-08	0.000592	1.75e-08
Kleibergen–Paap *F*-statistic	13.28	56.69	17.14	31.84	7.022	20.94	11.63	22.40
Pesaran–Taylor reset statistic	0.00537	0.18	0.136	0.00349	0.0120	1.497	1.669	0.007
Pesaran–Taylor *p*-value	0.942	0.668	0.712	0.953	0.913	0.221	0.196	0.935

Note
Robust standard errors in brackets.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

In all four outcome models expenditure has a significant negative effect on mortality and the all service measure of need has a significant positive effect. The squared value of the measure of need is also positive and significant in the cancer outcome equation. In the respiratory outcome model, there is an additional indicator of need – the proportion of the population that are permanently sick – and this is both positive and statistically significant. The diagnostic statistics suggest that, in all four cases, own programme expenditure is endogenous and that the instruments are valid. They also suggest that the instruments are relevant. There is no evidence that the instruments are weak in three of the four outcome results. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

However, the Kleibergen–Paap *F*-statistic for the respiratory disease outcome model is 7.022 and this is less than the 'critical' target of 10.0. This indicates that the instruments may be weak and not good predictors of the programme expenditure. However, if we re-estimate this model having dropped the least significant instrument, the coefficient on own programme expenditure becomes –2.622 and is significant at the 1% level. Moreover, there is now no evidence of weak instruments (the Kleibergen–Paap *F*-statistic is 11.025) and it is this coefficient that we use for the respiratory outcome model in the cost of a life-year calculations below.

In three of the four expenditure models both the need and budget variables have a positive and significant effect on own programme expenditure. In addition, the proxy for need in other programmes is negative and significant in all four cases. The diagnostic statistics suggest that, for all four expenditure models, expenditure is endogenous and the instruments are valid. They also suggest that the instruments are relevant and there is no evidence that the instruments are weak. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

Cost of a life-year

The outcome and expenditure elasticities presented in *Table 4* can be used to calculate the cost of a life-year in each programme. These calculations – for both the big four programmes as well as for the other six programmes with mortality based outcome indicators – are shown in *Table 5*. The cost of a life (year) estimates presented in *Table 5* assume a 1% increase in each PCT's budget and are calculated as:

the cost of an additional life in a particular programme

= the change in expenditure in that programme/the change in mortality in that programme

= (annual spend × expenditure elasticity)/(annual mortality × outcome elasticity × expenditure elasticity)

and

the cost of an additional life-year in a particular programme

= the change in expenditure in that programme/the change in life-years lost in that programme

= (annual spend × expenditure elasticity)/(annual life-years lost × outcome elasticity × expenditure elasticity).

To illustrate this calculation let us calculate the cost of a life-year for, say, the cancer programme. The annual spend on cancer in 2006/7 is £4122M and the expenditure elasticity for the programme is 0.465 so that the change in expenditure associated with a 1% increase in each PCT's budget is £19.1673M (= 1% × £4122M × 0.465). The total number of life-years lost to cancer for 2006/7/8 totals 2,207,021 life-years and so the average annual loss is 735,674 life-years. The outcome elasticity for the cancer programme is 0.342 and the expenditure elasticity is 0.465 so the reduction in the number of life-years lost associated with a 1% increase in each PCT's budget is 1170 (= 1% × 735,674 life-years × 0.342 × 0.465). The cost of an additional life-year is therefore £19.1673M (the change in expenditure in the programme) divided by 1170 (the reduction in the number of life-years lost), and this equals £16,383.

TABLE 5 Cost of life-year estimates by PBC for PCT expenditure in 2006/7, 2007/8 and 2008/9

	Expenditure 2006/7, outcome 2006/7/8				Expenditure 2007/8, outcome 2007/8/9				Expenditure 2008/9, outcome 2008/9/10			
PBC	Spend (£M) 2006/7	Total life-years lost, < 75 years, 2006/7/8	Cost per YLG (£)	Cost per YLG adjusted for YLL coverage (£)	Spend (£M) 2007/8	Total life-years lost, < 75 years, 2007/8/9	Cost per YLG (£)	Cost per YLG adjusted for YLL coverage (£)	Spend (£M) 2008/9	Total life-years lost, < 75 years, 2008/9/10	Cost per YLG (£)	Cost per YLG adjusted for YLL coverage (£)
Cancer	4122	2,207,021	16,383	16,121	4573	2,189,685	17,165	16,891	4843	2,170,660	21,802	21,454
Circulatory problems	6161	1,361,634	9466	9390	6325	1,313,223	11,315	11,224	6655	1,285,026	11,779	11,685
Respiratory problems	3285	324,223	11,593	8961	3431	315,457	14,798	11,439	3994	311,034	21,307	16,470
Gastrointestinal problems	3700	345,908	20,892	11,929	3805	343,355	25,034	14,295	3989	341,884	25,662	14,653
Big four programmes summary	17,268	4,238,786	12,333	10,604	18,134	4,161,720	16,345	13,830	19,481	4,108,604	16,688	14,650
Infectious diseases	1053	106,552	630,798	630,798	1119	106,092	57,742	57,742	1201	100,078	71,432	71,432
Endocrine problems	1852	57,672	114,416	72,539	1997	55,492	190,745	120,932	2222	54,779	104,008	65,941
Neurological problems	2790	66,137	1,129,960	153,675	3165	64,873	431,749	58,718	3466	64,222	388,267	52,804
Genitourinary problems	3482	10,030	20,421,090	3,512,427	3439	8,529	652,096	112,160	3779	8004	877,038	150,851
Trauma and injuries	2892	30,000	N/A	N/A	2918	21,273	1,115,197	195,159	3255	6881	N/A	N/A

PBC	Expenditure 2006/7, outcome 2006/7/8				Expenditure 2007/8, outcome 2007/8/9				Expenditure 2008/9, outcome 2008/9/10			
	Spend (£M) 2006/7	Total life-years lost, < 75 years, 2006/7/8	Cost per YLG (£)	Cost per YLG adjusted for YLL coverage (£)	Spend (£M) 2007/8	Total life-years lost, < 75 years, 2007/8/9	Cost per YLG (£)	Cost per YLG adjusted for YLL coverage (£)	Spend (£M) 2008/9	Total life-years lost, < 75 years, 2008/9/10	Cost per YLG (£)	Cost per YLG adjusted for YLL coverage (£)
Maternity and neonates	3574	492,600	45,158	30,662	3662	489,170	204,168	138,630	3978	479,905	198,939	135,080
Other six programmes summary	15,643	762,991	258,046	146,108	16,300	745,429	274,309	99,428	17,901	713,869	254,794	112,674
All 10 programmes summary	32,911	5,001,777	£23,780	19,965	34,434	4,907,149	38,110	28,983	37,382	4,822,473	38,328	30,883
Other 13 programmes summary	34,985				39,223				41,016			
All 23 programmes	67,896		87,494	73,457	73,657		108,829	82,765	78,398		105,460	84,974

N/A, not applicable.

An integral part of the calculation of the cost of a life-year is the annual mortality (life-years lost) figure associated with a particular programme. Ideally, the ICD-10 coverage of the expenditure data should coincide with that of the mortality data. However, as shown in *Table 37* of *Appendix 2*, the ICD-10 coverage of the mortality data typically falls short of that for the expenditure data. Unless we adjust the annual mortality figure so that its ICD-10 coverage approximates that of the expenditure data, our cost of life (year) estimates will be too large because they will underestimate the mortality gain.

Table 5 reports cost of a life-year estimates both with and without this adjustment for ICD-10 coverage. Having incorporated this adjustment, the results show that the cost of a life-year for the big four PBCs is estimated as £10,604 and, for all 10 programmes with a mortality outcome measure, the estimate is £19,965. For all programmes, assuming a zero gain for the 13 PBCs without an outcome indicator, the corresponding estimate is £73,457.

If we assume that PBC 23 (largely primary care) generates a zero health gain (because the gains from primary care are already reflected in the mortality rates for disease-specific programmes) and that the gain attributable to the remaining 12 programmes is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes is £22,565.[s]

Non-primary care trust Department of Health funded expenditure

Primary care trust expenditure accounts for a large proportion of Department of Health expenditure but PCTs do not account for the Department's entire budget. In 2006/7 the Department of Health's gross expenditure totalled £83.5B. Charges raised £3.4B so net expenditure totalled £80.1B. Of this net expenditure, PCTs accounted for £67.3B (that is, 84%) and various other bodies accounted for the remaining £12.8B. A breakdown of this gross and net expenditure by major body is shown in *Table 70* of *Appendix 2*. The Department of Health has allocated net non-PCT expenditure across the 23 PBCs. Of the additional £12B of net expenditure, £11.2B (93%) has been allocated to PBC 23. This largely reflects (a) the allocation of almost all SHA expenditure to either PBC 23B ('other: SHAs including workforce development committees') or PBC 23X ('other: miscellaneous'); and (b) the allocation of almost two-thirds of Department of Health expenditure to PBC 23X ('other: miscellaneous'). The remaining £0.8B of additional net expenditure is spread across all PBCs according to various allocation rules and although this approach avoids allocating expenditure to the 'other: miscellaneous' category, this allocation of expenditure does not necessarily reflect actual expenditure.

The cost of a life (year) estimates presented above are based on the impact of a 1% exogenous change in total net PCT spend. All of our outcome and expenditure models have been estimated using net PCT expenditure, and all of our elasticities relate to this expenditure. Implicitly we assume that any budgetary shock only affects PCT funding and that it leaves non-PCT funding unchanged. Suppose instead we assume a 1% exogenous change in the Departmental budget. We have no information on how this Departmental budgetary shock is likely to be split between PCT and non-PCTs budgets. One might assume that the non-PCT budget is as responsive to a Departmental budgetary shock as is the PCT budget. If this was the case then it would add 17.7% to our cost of a life-year estimate for 2006/7. However, in the absence of any information about the responsiveness of the non-PCT budget, it is difficult to come to any firm conclusion about the impact of non-PCT expenditure on our cost of a life-year estimates.

2007/8 expenditure data and mortality data for 2007/8/9

Outcome and expenditure models were estimated using updated data for expenditure (from 2006/7 to 2007/8) and updated mortality data (from 2006/7/8 to 2007/8/9). *Appendix 2, Analysis of programme budgeting expenditure for 2007/8 and mortality data for 2007/8/9* presents detailed discussion of the findings including tables of results.

Outcome models

As before, we model outcome as a function of own programme expenditure and a measure of health-care need, where the latter is proxied by the measure of need as employed by the Department of Health for

resource allocation purposes.[t] There are, however, a few exceptions. For the respiratory programme we further included the square of the measure of need to improve model fit. In some other PBCs we found that the all service measure of need performed poorly and we replaced or supplemented this measure with either a more programme-specific measure (e.g. the epilepsy prevalence rate for neurological mortality) or with a better performing proxy for need (e.g. the percentage of residents born outside the EU for maternity/neonate mortality). These amendments improved model specification.[u] Full results for all programmes are presented in *Appendix 2, Table 81*; below is a summary of the findings.

Two sets of models were estimated for three of the big four programmes (cancer, respiratory problems and gastrointestinal problems). One of the two models used two instruments and so we report the instrument validity test statistic. In all three cases we failed to reject the null hypothesis of instrument validity. However, there is some evidence of weak instruments (at least in the respiratory and gastrointestinal programmes) and if we dropped one instrument and re-estimated the model, evidence of instrument weakness disappeared. The removal of one instrument has little impact on the coefficient on expenditure and it is this coefficient that we use below in our cost of a life-year calculations reported in *Table 5*.

For the big four programmes the need variable has a positive and significant effect on mortality, and expenditure has the anticipated negative effect. The diagnostic statistics reveal that, in all four PBCs, own programme expenditure is endogenous and that the instruments are valid. They also suggest that the instruments are relevant and there is no evidence that they are weak in the models with one excluded instrument. The Pesaran–Taylor test reveals no evidence of model misspecification.

The outcome results for the other programmes are similar to but more diverse than those for the big four programmes. This is to be anticipated because mortality is a much rarer outcome in these programmes than it is in the big four programmes. Own programme expenditure is not endogenous in four of these programmes, but we retain the IV estimator for three of these four because this yields more plausible results than the OLS estimator (the results are more plausible in the sense that the signs on the coefficients are more in line with our prior expectations).[v]

Expenditure has the anticipated negative effect on mortality in the endocrine problems programme but this is not statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that the diabetes prevalence rate is positively associated with mortality, as is a measure of deprivation (the IMD2007).

Mortality from epilepsy is negatively and significantly associated with expenditure in the neurological programme. Both the all service need for health care and the epilepsy prevalence rate are positively and significantly associated with mortality in this programme.

Expenditure has a negative and statistically significant effect on mortality (from renal problems) in the genitourinary problems programme. The prevalence of lone parent households is positively associated with mortality.

Expenditure has the anticipated negative effect on mortality in the infectious disease programme and this is statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that a measure of need associated with HIV is positively associated with mortality, as is a measure of deprivation (the IMD2007).

Expenditure has the anticipated negative effect on mortality in the maternity and neonates programme but the estimated coefficient is not statistically significant. In this PBC the generic all service measure of need has been replaced with two other indicators of deprivation – the proportion of residents born outside the EU and the proportion of those aged 16–74 years without any qualifications – both of these are positively associated with mortality.

Finally, expenditure and need have the anticipated effects on mortality in the trauma and injuries programme. In addition, the proportion of households without access to a car is negatively associated with mortality from fractures (perhaps access to a car facilitates involvement in serious road traffic accidents), and the proportion of residents that are students is positively associated with mortality from fractures.

The relevant statistical test suggests that expenditure is endogenous in 6 of the 10 programmes but we have retained the IV estimates for three of the other four programmes because they provide plausible results. The Hansen–Sargen test suggests that the selected instruments are valid, and the Kleibergen–Paap LM statistic suggests that they are relevant (i.e. correlated with the endogenous regressor). With the possible exception of the trauma and injuries programme, the Kleibergen–Paap *F*-statistic suggests that we do not have a problem with weak instruments.[w] Finally, the Pesaran–Taylor reset test statistics and the Ramsey reset *F*-statistics reveal no evidence of misspecification.

Expenditure models

The majority of the expenditure models contain the three variables: the PCT budget, a proxy for the own programme need for health care, and a proxy for the need for health care in other programmes. The budget term is positive in all 11 models and it is statistically significant in 8 of these 11 models.

The usual proxy for the own programme need for health care (i.e. the all service measure of need) is present in six of the models and it is significant in five of them. Its presence is supplemented with the addition of its squared value to improve model fit in the respiratory problems programme. In some programmes (e.g. the endocrine, metabolic and nutritional, and neurological),[x] we have replaced and/or supplemented the all service measure of need with a more programme specific measure (e.g. the diabetes prevalence rate and the epilepsy prevalence rate) and these measures of need have the anticipated positive impact on expenditure.

In addition, in a couple of other programmes we have used alternative proxies for the own programme need (e.g. with the use of the Department of Health's measure of maternity need in the maternity/neonates expenditure equation). Full results for all programmes are presented in *Appendix 2, Table 82*; below is a summary of the findings.

For 8 of the 11 programmes we have used the all-cause mortality rate less own programme mortality rate as the proxy for the need for health care in other programmes, and the coefficient on this term is negative in seven programmes and statistically significant in six of the seven. In three programmes – maternity/neonates, GMS/PMS and trauma and injuries – we have used the all-cause mortality rate as the proxy for the need for health care in other programmes due to difficulties associated with the measurement of the own programme mortality rate. The coefficient on this term is not significant in any of the three models.

The relevant statistical test suggests that expenditure is endogenous in 6 of the 11 programmes but we have retained the IV estimates for two other programmes (GMS/PMS and trauma and injuries) because the IV estimator provides more plausible results. In the other three programmes we report OLS results.

The Hansen–Sargen test suggests that the selected instruments are valid, and the Kleibergen–Paap LM statistic suggests that they are relevant (i.e. correlated with the endogenous regressor). The Kleibergen–Paap *F*-statistic suggests that we do not have a problem with weak instruments. Finally, the Pesaran–Taylor reset test statistics and the Ramsey reset *F*-statistics reveal no evidence of model misspecification.

Calculation of the cost of a life and life-year

Expenditure and outcome elasticities for preferred models are used to calculate the cost of a life-year, both for individual programmes and for all programmes collectively. The relevant figures are summarised in *Table 5*.[y] The cost per YLG is £13,830 for the big four programmes and £28,983 for all 10 programmes

with a mortality-based outcome indicator. These represent 30% and 45% increases on the respective costs for the previous year (i.e. using expenditure data for 2006/7 and mortality data for 2006/7/8).

If we assume that the other 13 programmes (all without a mortality-based outcome indicator) offer no health gain, then the cost per life-year across all PCT expenditure is £82,765. This is up from £73,457 using data for the previous year (an increase of 13%).

In addition, if we assume that PBC 23 generates a zero health gain and that the gain attributable to the remaining 12 programmes is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes is £31,846 (it was £22,565 using data for the previous year).

The next section presents outcome and expenditure models using programme budget data for 2008/9 and mortality data for 2008/9/10, and it explores the reasons for the increase in the cost of an additional life-year identified in this section.

2008/9 expenditure data and mortality data for 2008/9/10

Outcome and expenditure models were estimated using updated data for expenditure (from 2007/8 to 2008/9) and updated mortality data (from 2007/8/9 to 2008/9/10). Detailed results for the outcome model and expenditure model are shown in *Appendix 2, Tables 85* and *86* respectively. First-stage regressions for these IV models can be found in *Tables 99* and *100* in the *Annex* to *Appendix 2*.

Outcome models

The majority of the outcome models contain the two variables: own programme expenditure and a measure of the need for health care (the measure of need as employed by the Department of Health for resource allocation purposes[z]). For the respiratory disease programme we have added the square of the need measure to improve the model fit. In other PBCs (e.g. for the endocrine, metabolic and nutritional), we found that the all service measure of need performed poorly and we have replaced it with a more programme specific measure (e.g. the diabetes prevalence rate) or with a better performing proxy for need (e.g. the percentage of residents born outside the EU for maternity/neonate mortality).[aa]

The relevant statistical test suggests that expenditure is endogenous in 6 of the 10 programmes but we have retained the IV estimates for the other four because they provide plausible results. The Hansen–Sargen test suggests that the selected instruments are valid, and the Kleibergen–Paap LM statistic suggests that they are relevant (i.e. correlated with the endogenous regressor). The Kleibergen–Paap *F*-statistic suggests that we do not have a problem with weak instruments. Finally, the Pesaran–Taylor reset test statistics reveal no evidence of misspecification.

In all of the big four programmes the need for health-care variable has a positive and significant effect on mortality, and expenditure has the anticipated negative effect. As we have noted before, the outcome results for the other programmes are similar to, but more diverse than, those for the big four programmes. This is to be anticipated because mortality is a much rarer outcome in these programmes than it is in the big four programmes.

Expenditure has the anticipated negative effect on mortality in the endocrine problems programme and this is statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that the diabetes prevalence rate is positively associated with mortality, as is a measure of deprivation (the IMD2007).

Expenditure has a negative but statistically insignificant impact on mortality from epilepsy in the neurological programme, and the all service indicator of the need for health care is positively and significantly associated with mortality in this programme.

Expenditure also has a negative but not statistically significant effect on mortality (from renal problems) in the genitourinary problems programme. The prevalence of lone parent households is positively associated with mortality.

Expenditure has the anticipated negative effect on mortality in the infectious disease programme and this is statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that a measure of need associated with HIV is positively associated with mortality, as is a measure of deprivation (the IMD2007).

Expenditure has the anticipated negative effect on mortality in the maternity and neonates programme. In this PBC the coefficient on the generic all service measure of need is positive but not significant. It has been supplemented with two other indicators of deprivation – the proportion of residents born outside the EU and the proportion of those aged 16–74 years without any qualifications – and both of these are positively associated with mortality.

Finally, we were unable to develop a plausible outcome model for the trauma and injuries programme.

Expenditure models

The majority of expenditure models contain the three variables: the PCT budget, a proxy for the own programme need for health care, and a proxy for the need for health care in other programmes.

The budget term is positive and statistically significant in 10 of the 11 models.

The usual proxy for the own programme need for health care (i.e. the all service measure of need) is positive and significant in 5 of the 11 results. In a couple of programmes (respiratory disease and endocrine problems) we have added the squared value of need to improve the model fit and in both cases this term is positive and significant. In some programmes (e.g. the endocrine PBC and the neurological PBC), we have replaced and/or supplemented the all service measure of need with a more programme-specific measure (e.g. the diabetes and the epilepsy prevalence rates) and these usually have a positive and significant impact on expenditure. In addition, in a couple of programmes we have used alternative proxies for own programme need (e.g. with the use of the Department of Health's measure of maternity need in the maternity/neonates expenditure equation and the use of HIV need in the infectious diseases programme).[ab]

For 8 of the 11 programmes we have used the all-cause mortality rate less the own programme mortality rate as the proxy for the need for health care in other programmes, and the coefficient on this term is negative in seven programmes and statistically significant in six of the seven. In three programmes – maternity/neonates, GMS/PMS and trauma and injuries – we have used the all-cause mortality rate as the proxy for the need for health care in other programmes due to difficulties associated with the measurement of the own programme mortality rate. The coefficient on this term is negative but not significant in these three models.

The relevant statistical test suggests that expenditure is endogenous in 5 of the 11 programmes but we have retained the IV estimates for two further programmes (endocrine problems and maternity/neonates) because the IV estimator provides more plausible results than the OLS estimator. In the other four programmes we report OLS results.

The Hansen–Sargen test suggests that the selected instruments are valid, and the Kleibergen–Paap LM statistic suggests that they are relevant (i.e. correlated with the endogenous regressor). The Kleibergen–Paap *F*-statistic suggests that we do not have a problem with weak instruments. Finally, the Pesaran–Taylor reset test statistics and the Ramsey reset *F*-statistics reveal no evidence of model misspecification.

Calculation of the cost of a life and life-year

Expenditure and outcome elasticities for our preferred models are used to calculate the cost of a life-year, both for individual programmes and for all programmes collectively. This results in the cost per YLG having increased slightly compared with using the previous expenditure and mortality data set (i.e. for 2007 and 2007/8/9 respectively): increasing from £13,830 to £14,650 for the big four programmes and from £28,983 to £30,883 for all 10 programmes with a mortality-based outcome indicator. If we assume that the other 13 programmes offer no health gain, then the cost per life-year across all PCT expenditure has increased from £82,765 in 2007/8 to £84,974 in 2008/9.

In addition, if we assume that PBC 23 generates a zero health gain and that the gain attributable to the remaining 12 programmes is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes in 2008/9 is £33,333. This is a 5% increase on the figure (£31,846) for the previous year.

Comparing the cost of life-year estimates associated with different data sets

Table 6 presents expenditure and outcome elasticities for the five combinations of expenditure and outcome data that have been used to estimate our model. It also reports the corresponding unadjusted cost of life-year estimates (i.e. estimates that are unadjusted for the mismatch in the ICD-10 coverage of the expenditure and mortality data). It is clear from this *Table 6* (see row 13) that the (unadjusted) cost of a life-year for the 10 programmes with a mortality-based outcome indicator fluctuated around £22,000 for the first three sets of estimations (see columns M–O). However, using the two most recent sets of expenditure data (i.e. for 2007/8 and then for 2008/9), the figures in the table suggest that this cost has increased to about £38,000.

What are the proximate causes of this increase? Recall that the cost of a life-year is calculated as:

$$\frac{\text{The change in expenditure associated with a 1\% budget increase}}{\text{The change in the number of life-years lost associated with this increase}}$$

For 2006/7 (using mortality data for 2006/7/8) and for the 10 programmes with a mortality-based outcome indicator, the change in expenditure associated with a 1% budget increase is £184.53M and the change in the number of life-years lost associated with this increase is 7760 (see *Appendix 2*, *Table 67* for the calculation of these figures). Thus the cost of a life-year is £23,780 (= £184.53M/7760).

For 2007/8 (using mortality data for 2007/8/9) and for the 10 programmes with a mortality-based outcome indicator, the change in expenditure associated with a 1% budget increase is £257.94M and the change in the number of life-years lost associated with this increase is 6768 (see *Appendix 2*, *Table 83* for the calculation of these figures). Thus the cost of a life-year is £38,110 (= £257.94M/6768).

It is clear that the 60% increase in the cost of a life-year between 2006/7 and 2007/8 is largely attributable to (a) the 40% increase in the additional expenditure (up from £184.53M to £257.94M) directed towards these 10 programmes following a 1% budget increase; and (b) the 12% decline in the number of life-years saved by this increase in expenditure (down from 7760 to 6768 life-years).

The rise in the share of the budget increase directed towards these programmes can be attributed to the increase in the implied expenditure elasticity associated with these 10 programmes (up from 0.561 to 0.749). The decrease in the number of years of life saved appears to be due to (a) an overall reduction in the (absolute) size of the outcome elasticities; and (b) a shift in the additional expenditure towards those programmes with a relatively high cost of a life-year. For example, the cost of a life-year for the 'small six' programmes is much larger than for the 'big four PBCs'. However, in 2007/8 the spend elasticity for the small six increases from 0.561 to 0.961 (71%) whereas the expenditure elasticity for the big four rises from 0.528 to 0.559 (6%). A similar pattern – of additional expenditure shifting away from the low

TABLE 6 Expenditure and outcome elasticities for five combinations of expenditure and outcome data, and corresponding (unadjusted) cost of life-year estimates

A	B	C	D	E	F	G	H	I
PBC		Spend elasticities					Outcome elasticities	
		Using spend for 2005 and mortality for 2002/3/4	Using spend for 2006 and mortality for 2004/5/6	Using spend for 2006 and mortality for 2006/7/8	Using spend for 2007 and mortality for 2007/8/9	Using spend for 2008 and mortality for 2008/9/10	Using spend for 2005 and mortality for 2002/3/4	Using spend for 2006 and mortality for 2004/5/6
1	Cancer	0.968	0.548	0.465	0.890	0.525	−0.394	−0.337
2	Circulatory problems	0.682	0.701	0.540	0.293	0.648	−1.370	−1.447
3	Respiratory problems	0.849	0.718	0.679	0.536	0.652	−1.574	−3.507
4	Gastrointestinal problems	0.772	0.667	0.446	0.622	0.456	−2.018	−2.137
5	All big four PBCs	0.801	0.660	0.528	0.559	0.579	−0.941	−1.083
6	Infectious diseases	0.742	0.731	0.792	1.436	1.545	−0.152	−0.030
7	Endocrine problems	0.425	0.966	0.953	0.264	0.484	−0.244	−0.812
8	Neurological problems	1.111	0.648	0.616	1.035	0.98	−0.182	−0.098
9	Genitourinary problems	1.041	0.837	0.912	1.004	0.697	−0.034	−0.073
10	Trauma and injuries	0.627	0.617	0.358	1.686	1.344	−1.332	−0.527
11	Maternity and neonates	0.388	0.601	0.224	0.514	0.975	−0.237	−0.035
12	All small six PBCs	0.780	0.717	0.596	0.961	0.962	−0.262	−0.122
13	All 10 PBCs with mortality	0.792	0.687	0.561	0.749	0.762	−0.844	−0.940
14	All 23 PBCs assuming zero gain in PBCs without mortality indicator							
15	GMS/PMS	0.926	0.759	0.739	0.563	0.494	N/A	N/A
16	All 23 PBCs assuming zero gain in PBC 23 but average gain in other PBCs without a mortality indicator							

N/A, not applicable.
The spend and outcome elasticities reported for groups of programmes are the implied elasticites calculated from the totals for the relevant individual programmes [i.e. group spend elasticity = (PBC spend × PBC spend elasticity)/PBC spend, and group outcome elasticity = (PBC mortality × PBC outcome elasticity)/PBC mortality]. For the purpose of the calculation of the group outcome elasticity, we have used the YLL as the mortality indicator. The implied group elasticities cannot be used to calculate directly the cost of a life (year) for a group of PBCs. Instead, the latter should be calculated by summing across the change in spend and the change in mortality for the individual PBCs within the group. For further details see, for example, *Table 67* in *Appendix 2*.

J	K	L	M	N	O	P	Q
			Cost of an additional life-year (£) (unadjusted for YLL coverage)				
Using spend for 2006 and mortality for 2006/7/8	Using spend for 2007 and mortality for 2007/8/9	Using spend for 2008 and mortality for 2008/9/10	Using spend for 2005 and mortality for 2002/3/4	Using spend for 2006 and mortality for 2004/5/6	Using spend for 2006 and mortality for 2006/7/8	Using spend for 2007 and mortality for 2007/8/9	Using spend for 2008 and mortality for 2008/9/10
−0.342	−0.365	−0.307	13,741	16,518	16,383	17,165	21,802
−1.434	−1.277	−1.319	8328	8725	9466	11,315	11,779
−2.622	−2.205	−1.808	20,601	8747	11,593	14,798	21,307
−1.536	−1.328	−1.364	18,303	15,795	20,892	25,034	25,662
−0.965	−0.872	−0.825	12,855	10,783	12,333	16,345	16,688
−0.047	−0.548	−0.504	215,054	1,036,377	630,798	57,742	71,432
−0.842	−0.566	−1.170	371,601	112,882	114,416	190,745	104,008
−0.112	−0.339	−0.417	503,201	1,241,253	1,129,960	431,749	388,267
−0.051	−1.855	−1.615	29,144,918	12,384,965	20,421,090	652,096	877,038
0	−0.369	0	282,132	548,767	N/A	1,115,197	N/A
−0.482	−0.110	−0.125	17,490	631,700	45,158	204,168	198,939
−0.392	−0.254	−0.300	295,074	449,706	258,046	274,309	254,794
−0.877	−0.778	−0.747	21,256	20,893	23,780	38,110	38,328
			56,799	62,718	87,494	108,829	105,460
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			24,200	23,697	26,876	41,875	41,369

cost PBCs – can be seen within the big four programmes. However, it is not clear why such rather dramatic changes should have taken place.

If we correct the cost of life-year estimates adjusting for the mismatch in the ICD-10 coverage of the expenditure and mortality data, these reveal similar increases in the cost of a life-year between 2006/7 on the one hand and 2007/8 and 2008/9 on the other. The cost of a life-year increased from £19,965 in 2006/7 to £28,983 in 2007/8 for the 10 programmes with mortality rate, an increase of 45%; and it increased from £22,565 to £31,846 for all programmes if we assume a zero health gain in PBC 23 and the same gain in the other 12 programmes as in the 10 with a mortality rate (an increase of 41%).

A potential reason for this apparent step change in the cost of a life-year is the adjustment that was made to the methodology for the collection of the 2007/8 PB data. In previous years expenditure that was not directly attributable to a particular programme category was apportioned using admitted patient care percentages.[ac] In other words, if *x*% of total admitted patient care expenditure was allocated to PBC 1, then *x*% of all expenditure that was not directly attributable to a particular programme category was also allocated to PBC 1. With effect from 2007/8, however, NHS organisations were asked to select an appropriate basis for the apportionment of this non-programme-specific expenditure and that, where no reasonable basis existed, such expenditure was to be allocated to the 'other – miscellaneous' (PBC 23X) category.

The Department of Health estimates that this allocation rule change increased the amount of expenditure attributed to PBC 23X by £700M. It will also, of course, have reduced expenditure across other programmes by the same amount in total. However, not all programmes will have been equally affected; PBCs that are more heavily inpatient based would have 'lost' expenditure whereas others, such as learning disabilities, social care and mental health, will have 'lost' considerably less. In addition, not all PCTs will have been equally affected because each will have employed different apportionment rules for the non-programme-specific expenditure (Bryn Shorney, Department of Health, 2012, personal communication).

Although this allocation rule change has considerably increased the estimated cost of a life-year, we believe that this rule change has led to a more accurate allocation of expenditure across PBCs, and that the more recent estimates of the cost of a life-year (for 2007/8 and 2008/9) are more accurate than those for the earlier years (for 2005/6 and 2006/7).

Adjusting the cost of a life-year estimates to constant prices

The estimates of the cost of a life-year presented above are all at current prices. To put them on a constant price basis, we need an index of pay and price inflation for the labour and goods/services purchased by the NHS. Curtis[87] reports a pay and prices index for HCHS and this implies an inflation rate of 3.7% in 2006/7, 2.9% in 2007/8 and 3.9% in 2008/9.[ad] If we assume that similar inflation rates also apply to the purchase of pharmaceuticals and the provision of primary care (items that are excluded from the HCHS index), then we can use these figures to put the estimates of the cost of a life-year on a constant price basis.

For example, if we assume that PBC 23 generates a zero health gain and that the gain attributable to the 12 programmes without a mortality indicator is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes in 2008/9 is £33,333 at current (2008/9) prices. The cost for 2007/8 is £31,846 at current (2007/8) prices or £33,088 at constant (2008/9) prices, and the figure for 2006/7 is £22,565 at current (2006/7) prices or £24,125 at constant (2008/9) prices. The conversion of the costs from a current to constant price basis has relatively little impact because the inflation rate over the relevant period is quite small.

Summary and concluding remarks

The findings presented in this report build on four previous studies. These studies and the results presented here draw on the availability of two new data sets to obtain empirical estimates of the relationship between mortality and expenditure across all English local health authorities.

In this research we have extended the previous studies in several ways. First, we have derived plausible outcome and expenditure models for a larger number of programmes (10) than previous studies.

Second, we relate expenditure in time period t to mortality in that period (t) and in the next two periods ($t+1$ and $t+2$). In other words, we assume that the health benefits associated with expenditure occur either in the same period as the expenditure or in the next two periods. This is an improvement on past practice where data constraints forced researchers to relate expenditure to the current and two previous periods.[ae] When we re-estimated our models using expenditure data for 2006/7 and mortality data for 2006/7/8, we found that the cost of a life-year across the 10 programmes with a mortality-based outcome indicator is £23,780 (up from £20,893 when expenditure data for 2006/7 is combined with mortality data for 2004/5/6; an increase of 14%).

Third, we have noted the mismatch in the ICD-10 coverage of the expenditure and mortality data. If we adjust the calculation of the cost of a life-year for 2006/7 for this mismatch then the cost of a life-year across the 10 programmes with a mortality-based outcome indicator declines from £23,780 to £19,965 (a decrease of 16%).

Fourth, previous estimates of the cost of a life-year have been for individual programmes of care. In this report we have presented estimates of the cost of a life-year for an enlarged number of programmes and, with the aid of assumptions about the productivity (health gain) of programmes without a meaningful mortality-based outcome indicator, we have extended our individual programme estimates to incorporate expenditure across all programmes of care. Thus for 2006/7, the cost of a life-year for those PBCs with a mortality-based outcome indicator is £19,965. If we assume (a) that the health gains associated with PBC23, which includes primary care and workforce training expenditure, are reflected in the mortality rates for disease-specific programmes and (b) that the average health gain across the other programmes without a mortality-based outcome indicator is the same as that for those PBCs with a mortality-based outcome indicator, then the cost of life-year across all programmes is £22,565.

Fifth, we have extended our cost of life-year estimates beyond 2006/7. Re-estimation of our model using budgeting expenditure for 2007/8 generates an all programme cost of a life-year estimate of £31,846, and re-estimation of our model using budgeting expenditure for 2008/9 generates a similar cost of a life-year estimate (£33,333). Together, the last two estimates suggest that there has been step change in the cost of a life-year, and that this appears to have occurred between 2006/7 and 2007/8. The cost of a life-year estimates are very similar up to and including 2006/7, and they are very similar for 2007/8 and 2008/9. However, there is a substantial difference between the figures for 2004/5, 2005/6 and 2006/7 on the one hand (at about £22,000), and for 2007/8 and 2008/9 on the other (at about £33,000). The reason for this step change is not obvious but it might be due to changes in the algorithm used by the Department of Health to allocate non-admitted patient care activity to budget categories. Although this allocation rule change has considerably increased the estimated cost of a life-year, we believe that this rule change has led to a more accurate allocation of expenditure across PBCs, and that the more recent estimates of the cost of a life-year (for 2007/8 and 2008/9) are more accurate than those for the earlier years (for 2005/6 and 2006/7). A summary of the estimates of the cost of a life-year adjusted for the mismatch between ICD-10 chapters for expenditure and mortality are provided in *Table 7*.

TABLE 7 Adjusted cost of life-year estimates for various combinations of programmes

A	B	C	D	E
PBC		Cost per life-year (£) (adjusted for ICD-10 coverage of spend and mortality data)		
		2006/7	2007/8	2008/9
1	Cancer	16,121	16,891	21,454
2	Circulatory disease	9390	11,224	11,685
3	Respiratory problems	8961	11,439	16,470
4	Gastrointestinal problems	11,929	14,295	14,653
5	All big four programmes	10,604	13,830	14,650
6	Other six programmes with a mortality rate	146,108	99,428	112,674
7	All 10 PBCs with a mortality rate	19,965	28,983	30,883
	(a) If we assume a zero health gain in those PBCs without a mortality rate . . .			
8	All 23 programmes	73,457	82,765	84,974
	. . . or (b) if we assume a zero gain in PBC 23 and that the average gain from the			
	the 10 PBCs with a mortality rate is applied to the remaining programmes			
9	All 23 programmes	22,565	31,846	33,333

Note that the figures for 2006/7 relate to the use of mortality for 2006/7/8 combined.

Virtually all of the cost of a life-year estimates presented in this report are calculated at current prices. However, it is possible to put them on a constant price basis using the HCHS pay and prices index.[87] For 2006/7, 2007/8 and 2008/9 this index recorded an annual rate of inflation of about 3.5% and so the impact of this constant price adjustment is fairly minimal. For example, if we assume that PBC 23 generates a zero health gain and that the gain attributable to the 12 programmes without a mortality indicator is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes at constant 2008/9 prices is £33,333 for 2008/9, £33,088 for 2007/8, and £24,125 for 2006/7.

Finally, although previous results and our current models 'pass' the appropriate statistical tests and, in particular, the Hansen–Sargen test for valid instruments, we are aware that this test might be unable to detect the presence of invalid instruments in some circumstances and that the validity of IVs is often open to question. Responding to this, several studies[88,89] have suggested that researchers using IV techniques should subject the estimated coefficient on the endogenous variable to a sensitivity analysis. We undertake a comprehensive sensitivity analysis for the outcome equation for each of the big four models. This sensitivity analysis reveals that uncertainty associated with instrument validity has little effect on our estimate of the cost of a life-year but it does increase the degree of uncertainty associated with this estimate.

We recognise that this study has a number of limitations. The estimates of the cost of an additional life-year for programmes with a mortality-based outcome indicator are unadjusted for the QoL during the additional year. Accordingly, the quoted costs will be an underestimate of the QALY cost of a life-year to the extent that additional life-years are not in perfect health. In previous studies we have noted that a rudimentary adjustment for this issue using Health Outcomes Data Repository (HODaR) data increased the cost of a life-year by about 50–60%.[60,63]

At the same time, however, the estimated costs will exaggerate the cost of an additional QALY for those programmes with a mortality-based outcome indicator because they ignore any health benefits that are not associated with a reduction in mortality. In other words, expenditure that improves the QoL (e.g. cancer palliative care) but which does not extend the length of life is implicitly given a zero health gain value.

In addition, the expenditure data relate to expenditure on all patients whereas the mortality data are based on a LE of 75 years. Thus implicitly our calculations attribute a zero health gain to all expenditure on those aged over 75 years. To illustrate the magnitude of the potential health gain ignored by this restriction, note that in a recent study of costs associated with all inpatient and outpatient activity (excluding mental health), those aged over 75 years accounted for 25% of all costs in 2007/8.[86]

The results presented in this study are all from the estimation of the relationship between expenditure and mortality using data for a single time period. With the availability of several years of data for both expenditure and mortality, we wanted to estimate a panel data model because a panel can offer advantages over a one period model (e.g. it is better able to handle any unobserved heterogeneity across PCTs). However, most of the instruments employed here are based on the 2001 Census[80] and, thus, time invariant, rendering them of little use in panel data modelling.

Chapter 4 Translating mortality effects into life-years and quality-adjusted life-years

Introduction

This chapter presents an overview of how the results of the econometric work undertaken to estimate the link between NHS spending and mortality, which was summarised in the previous chapter and detailed in *Appendix 2*, can be translated into effects on life-years and QALYs.

In this chapter we present three sequential steps of analysis which lead to estimates of the overall cost per QALY threshold for the NHS:

i. In *From mortality to life-years* we reconsider how the estimated effects on mortality from the econometrics work conducted in *Chapter 3* might better translate in to life-years by exploring the limitations of mortality data available at PCT level and the published YLL figures presented. We explore how these estimates might be improved using additional data and analysis.
ii. In *Adjusting life-years for quality-of-life* we consider how these estimates of life-year effects might be adjusted for the QoL in which they are lived, taking account of the gender and the age at which life-years are gained or lost as well as the disutility associated with particular diseases.
iii. In *Including quality-of-life effects during disease* we explore ways to also take account of those effects on health not directly associated with mortality and life-year affects (i.e. the 'pure' QoL effects) to estimate an overall cost per QALY threshold.

This sequence of analysis is set out and explained based on the analysis of 2006 expenditure and mortality data from 2006 to 2008. In *Chapter 5, Re-estimating the cost per quality-adjusted life-year threshold using more recent data* we present estimates for 2008 expenditure and 2008–10 mortality data using the same methods and discuss the uncertainties associated with these estimates. As in the previous chapter much of the detail of data and analysis that supports this overview is presented in an appendix (see *Appendix 3*). At the end of each section we present a summary which includes a central 'best' estimate as well as extreme lower and upper bounds for the cost per life-year and cost per QALY threshold.

The core assumptions which underpin these three values are common across the above mentioned sections. The central or 'best' estimate is based on two assumptions: one conservative and the other more optimistic with respect to the health effects associated with expenditure. The first is that the health effects of changes in 1 year of expenditure are restricted to 1 year. This is implicit in the estimates of outcome elasticities presented in the previous chapter.[a] This is likely to underestimate effects on mortality as expenditure that reduces mortality risk for an individual in 1 year may well also reduce their risk over subsequent years; possibly over the whole of their remaining disease duration. Expenditure may also prevent disease in future patient populations. Therefore, total health effects will be underestimated and the cost per life-year or QALY threshold will be overestimated. Although undoubtedly conservative, it may be offset to some extent by the more optimistic assumption used to translate mortality effects into life-years. Any death averted by expenditure in 1 year is assumed to return the individual to the mortality risk of the general population, i.e. the YLG associated with each death averted are based on what would have been their LE taking account of their of age and gender (using life tables for the general population).

The extreme upper and lower bounds for cost per life-year and cost per QALY thresholds are based on making both assumptions either optimistic (providing the lower bound for the threshold) or both conservative (an upper bound for the threshold). The lower bound is based on assuming that health effects are not restricted to 1 year but apply to the remaining disease duration for the population at risk during

the expenditure year (although this still does not account for the effects of expenditure on preventing disease). The upper bound is based on the combination of assuming that health effects are restricted to 1 year and that any death averted is only averted for the minimum duration consistent with the mortality data used to estimate the outcome elasticities in *Chapter 3* (see *Summary of cost per life-year estimates* for a more detailed discussion). It is very important to note that the lower and upper bounds represent extreme values rather than alternative but plausible views that could reasonably be taken. We discuss this in more detail in *Chapter 5, Future research and improving estimates* and explain why establishing narrower bounds, which might retain some plausibility, has not been possible given the data available and therefore the analysis that has been feasible.

From mortality to life-years

In this section we summarise our examination of a number of issues associated with available PCT-based mortality data and the associated published estimates of YLL. We then examine how, given the limited information available about the population at risk in each PBC, we might take proper account of the fact that some of the observed deaths would have occurred anyway (had the same population not been at risk in the particular PBC) when estimating YLL (i.e. taking account of unobserved counterfactual deaths). This allows us to estimate the YLL that better reflects the effect of expenditure on the mortality observed in each PBC, and infer the excess deaths associated with each PBC. Finally we present cost per death averted and cost per life-year which accounts for the issues raised in this section.

Mortality and years of life lost coverage

The mortality data that is available at PCT level does not offer full coverage of all deaths across all the ICD-10 codes that make up each PBC (see *Table 37* in *Appendix 2* for how three-digit ICD-10 codes are mapped to PBCs). However, national (English) data are available that covers all deaths associated with all the ICD-10 codes that make up each PBC. Therefore, it is possible to adjust the incomplete reporting of mortality at PCT level (see *Chapter 3, Previous studies*) before applying the estimated outcome elasticities to calculate the deaths averted due to expenditure.[b] Applying published estimates of YLL per death to all the deaths averted provides the estimate of the cost per life-year reported in *Chapter 3*.

The published estimates of YLL (National Health Service Information Centre; NHS IC) used in *Chapter 3* only include deaths below the age of 75 years (but exclude deaths below age 1 year) and are based on the difference between age 75 years and the age of each death below 75 years. These estimates have the same limited coverage as PCT-level mortality data so are not available for all the ICD-10 codes that make up each PBC. Therefore, applying the available estimates of YLL per death to the estimated number of deaths averted requires an assumption that the YLL per death is similar for those groups of ICD-10 codes covered and not covered by the published YLL figures.

This can be examined by using national Office for National Statistics (ONS) data to calculate YLL in the same way as NHS IC, but with full coverage of all the ICD-10 codes that make up each PBC.[c] Although ONS data provides complete coverage and reports gender, age at death is only reported in 5-year ranges (these data are not available at PCT level so could not be used when estimating outcome elasticities in *Chapter 3*). Therefore, using ONS data to estimate YLL requires taking the mid-point of each range as the age of death, i.e. assuming reported deaths are equally likely over the range in which they are reported. For this reason it is not possible to precisely recover the published YLL figures using ONS data for those ICD groupings that can be precisely matched to the NHS IC coverage. However, the differences are small (see *Appendix 3, Table 102*), suggesting that taking the mid-point of each range as the age of death may be a reasonable approximation.

The differences between estimates of YLL based on ONS and NHS IC data are, however, much more significant and are reported in *Table 8*. These reflect differences in the distribution of ages at death between those groups of ICD-10 codes covered and not covered in the NHS IC figures. For example,

TABLE 8 Estimates of YLL for NHS IC and ONS

PBC		(1) Coverage of mortality data relative to spend data	(2) YLL < 75 years (NHS IC)	(3) YLL < 75 years, adjusted (NHS IC)	(4) YLL < 75 years, no adjustment needed (ONS)	(5) Difference from adjusted NHS IC to ONS (%)
1	Infectious diseases	1.00	35,517	35,517	40,928	15
2	Cancer	0.98	735,674	747,636	758,804	1
4	Endocrine problems	0.63	19,224	30,322	41,548	37
7	Neurological problems	0.14	22,046	162,100	93,755	–42
10	Circulatory	0.99	453,878	457,538	481,246	5
11	Respiratory	0.77	108,074	139,812	147,465	6
13	Gastrointestinal	0.57	115,303	201,931	177,532	–12
17	Genitourinary	0.17	3343	19,438	17,380	–11
18 + 19	Maternity and neonates	0.68	164,200	241,826	15,409	–94

NHS IC figures available at PCT level for PBC 7 (neurological problems) have low coverage of all deaths in this PBC [0.14 in column (1)]. The deaths that are reported in NHS IC are associated with epilepsy and the YLL [22,046 in column (2)] reflects the generally younger age at death in this group. When adjusted for full coverage [22,046/0.14 = 162,100 in column (3)] the estimated YLL is much greater than the YLL based directly on all deaths by age group reported in ONS. This difference in YLL reflects the fact that the deaths in PBC 7 which are not covered by NHS IC figures tend to be in older age groups so generate fewer YLL.

Using ONS data also allows deaths under the age of 1 year to be appropriately assigned to PBCs via the ICD-10 code in which they occurred (NHS IC YLL figures exclude deaths under 1 year), rather than assigning them all to PBC 18 + 19 as in the previous chapter.[d] This explains the large reduction in YLL for PBC 18 + 19 (maternity and neonates) as much of the mortality is reassigned to ICD-10 codes which contribute to other PBCs. As most of the deaths that are reassigned are allocated to PBC 1 (infectious diseases) the YLL for this PBC increases despite complete reporting of deaths at PCT level and full coverage by NHS IC figures (see also *Table 104* in *Appendix 3*).

Life expectancy and years of life lost

As noted above, the NHS IC estimates of YLL only include deaths below age 75 years and are based on the difference between age 75 years and the age of each death below 75 years. Implicitly this treats 75 years as the appropriate normal LE for males and females for the population at risk in each PBC. However, with the exception of maternity and neonates most deaths in PBCs occur above the age of 75 years and LEs are significantly > 75 years. For example, based on 2006–8 data, LE for the general population is 80.7 years for males and 84.4 years for females (considering age distribution) and even LE at birth is > 75 years (77.74 years for males and 81.88 years for females).[90]

Based on ONS data YLL can be recalculated using gender-specific LE for the general population.[e] When increasing LE two effects occur, both of which tend to increase estimates of YLL. First, more deaths are included in the YLL calculation (those that occur between age 75 years and LE) and second, each death previously counted below 75 years will generate 5.7 or 9.4 more YLL for males and females respectively. The effect on the number of deaths and the YLL for each PBC of using the LE of the general population is reported in *Table 9* [see columns (1), (2) and (3)].

TABLE 9 The difference in YLL by LE

PBC		(1) Deaths < 75 years (ONS)	(2) Deaths < LE (ONS)	(3) Difference in deaths due to increased LE (%)	(4) YLL < 75 years (ONS)	(5) YLL < LE (ONS)	(6) Difference in YLL due to increased LE (%)
1	Infectious diseases	2050	3710	81	40,928	62,051	52
2	Cancer	62,944	95,212	51	758,804	1,345,013	77
4	Endocrine	2367	4000	69	41,548	65,015	56
7	Neurological	5095	8975	76	93,755	145,526	55
10	Circulatory	41,487	82,098	98	481,246	916,170	90
11	Respiratory	14,000	30,500	118	147,465	310,326	110
13	Gastrointestinal	10,611	15,827	49	177,532	273,303	54
17	Genitourinary	1588	4197	164	17,380	39,098	125
18 + 19	Maternity and neonates	226	226	0	15,409	17,167	11

The number of deaths counted below LE increases for every PBC except for maternity and neonates because, as expected, all deaths are below age 75 years in PBC 18 + 19. However, YLL increases for all PBCs reflecting the additional years otherwise expected to be lived to an older LE. Of course including more of the deaths observed in each PBC and the greater YLL associated with them will generate more deaths averted and more YLGs when applying the same proportionate effects from the outcome elasticities estimated in *Chapter 3*. Therefore, the cost per death averted and cost per life-year threshold are lower using these figures than those reported in *Chapter 3* (see *Table 13* and *Table 107* in *Appendix 3* for a summary of the effects on the thresholds). However, there are good reasons why YLL figures calculated as the difference between age of death and LE are likely to be overestimated. This is dealt with in the next section (see *Years of life lost and accounting for counterfactual deaths*). In *Inferring excess deaths* we take account of the fact that some of the deaths observed in a PBC would have occurred anyway in a similar 'normal' population (i.e. the counterfactual population not at risk through membership of the PBC) so not all observed deaths are 'excess' and generate YLL.

Years of life lost and accounting for counterfactual deaths

The estimates of YLL based on ONS data overcome many of the limitations of the published NHS IC figures. However, the YLLs reported in *Tables 8* and *9*, are calculated in the same way as the NHS IC figures, by taking the difference between a fixed LE and the age at death of deaths observed below that LE. This will tend to overestimate the YLL for two reasons: (1) it does not account for the fact that not all deaths observed below LE are 'excess' deaths in the sense that some deaths would have occurred (at the same age) in a similar population not at risk in the PBC; and (2) some of the deaths observed above LE may be 'excess' deaths that would not otherwise have occurred at that age. The overall effect on YLL, and the cost per life-year, will depend on the number of deaths above and below LE that are excess. Therefore, estimates of YLL are required which take account of the 'counterfactual' deaths that would have occurred even if the population in the PBC was not at risk through membership of the ICD-10 codes that make it up, but faced the same mortality risks as the general population, accounting for the age and gender distribution of the PBC population.

Ideally, with reliable information about the size of the population at risk in each PBC and its age and gender distribution it would be possible to estimate the number of deaths that would be expected to occur had this population not been at risk, based on mortality data for the general population. The difference between deaths observed across all ages and the deaths expected to have occurred in

this matched 'normal' population would provide the number of 'excess' deaths by age and gender.[f] The YLL associated with each of these excess deaths is the LE conditional on gender and on surviving to the age at which the excess death occurred. The total YLL for the at risk population is simply the sum of these YLLs over all excess deaths, which could occur at any age. This YLL is equivalent to the area between the survival curve for the population at risk in a PBC and the counterfactual survival curve for the same population but not at risk from membership of the PBC. The difficultly is that routinely available data do not provide any information about the size of the population at risk or its age and gender distribution. All that is routinely available are observed deaths (by age and gender). Therefore, it is not possible to directly estimate excess deaths or compare survival curves.

Even if the size of the at risk population is unknown we can still use information that might be available about its age and gender distribution (or make reasonable assumptions) to estimate a matched 'normal' LE using life tables for the general population (such a LE summarises the area under the counterfactual survival curve). Unfortunately, it is not possible to also calculate the LE for the population at risk in the PBC (or represent the survival curve) without information about the size of the at risk population (if it was possible the difference between these life expectancies would approximate the YLL per patient at risk in a PBC).

Fortunately, we can still recover a consistent estimate of YLL using observed deaths and a LE that represents the normal LE of a matched population that is not at risk. This requires all observed deaths, both those that occur below and those that occur above this LE to be taken into account. Those deaths occurring below LE generate YLL – compared with the average of a matched population not at risk. However, we must also account for those deaths that occur at ages above LE. These deaths generate YLGs compared with the average of a matched population not at risk. Therefore, the appropriate estimate is a net YLL (i.e. YLL – YLG). In effect, by subtracting YLG from YLL we take account of the fact that not all deaths below LE are excess deaths but some deaths above LE are (see *Appendix 3* for more formal explanation of the equivalence of these ways of calculating YLL).[g]

Using the life expectancy of the general population

Routinely available data provides the age and gender of observed deaths but no information about the age and gender distribution of the at risk population itself. Using observed age and gender at death as an indication of the distribution of the at risk population will significantly overestimate the LE of a normal matched population insofar as a disease may be chronic (not all PBC mortality occurs on entry into the at risk population), and that PBC-related mortality risk may increase with age (see *Appendix 3, Table 114*).[h]

In the absence of additional external information the net YLL could be based on the LE of the general population, reflecting its current age and gender distribution. These are reported in *Table 10* and illustrate the impact of accounting for counterfactual deaths in the way described above. The YLL reported in column (5) of *Table 10* are calculated the same way and are the same as the figures previously reported [column (5) of *Table 9*]. That is, they do not account for deaths that would have otherwise occurred below LE or the very many deaths that occur above LE. With the exception of PBC 18 + 19 many deaths occur above the LE of the general population [see column (4) in *Table 10*] in all PBCs. As a consequence there are YLG associated with all other PBCs [see *Table 10*, column (6)] so the net YLL in column (7) are lower than YLL based on the same LE. Therefore, failure to account for counterfactual deaths would lead to an overestimate of the YLL associated with a PBC and the effects of expenditure on YLL. Consequently, the cost per life-year threshold would be underestimated (see *Table 13*).

However, these figures are only correct insofar as the distribution of age and gender in each PBC is similar to the general population. For example, if the at risk population tends to be younger the correct LE for the PBC will be lower and the net YLL will also tend to be lower. Similarly, if the at risk population tends to be older than the general population the correct LE will be higher and net YLL will also tend to be higher.[i] This explains the apparent net gain in YLL (negative net YLL) for PBC 17 (genitourinary) where most deaths occur at ages greater than the LE of the general population so that YLG exceeds YLL. As we are able to show later (see *Table 11*) this is because the age distribution in this PBC tends to be older than the general

TABLE 10 Net YLL using LE of the general population

PBC		(1) LE of males (years)	(2) LE of females (years)	Average 2006–8				
				(3) Deaths < LE	(4) Deaths > LE	(5) YLL	(6) YLG	(7) Net YLL
1	Infectious diseases	80.7	84.4	3710	3248	62,052	18,796	43,256
2	Cancer	80.7	84.4	95,213	35,597	1,345,038	175,350	1,169,689
4	Endocrine	80.7	84.4	4000	2764	65,016	15,864	49,152
7	Neurological	80.7	84.4	8975	6378	145,529	34,621	110,908
10	Circulatory	80.7	84.4	82,099	77,752	916,192	444,694	471,498
11	Respiratory	80.7	84.4	30,500	34,945	310,334	215,829	94,505
13	Gastrointestinal	80.7	84.4	15,827	8320	273,308	45,295	228,012
17	Genitourinary	80.7	84.4	4198	6427	39,099	40,530	–1431
18 + 19	Maternity and neonates	80.7	84.4	226	0	17,167	0	17,167

TABLE 11 Average age and LE for PBCs based on GBD

PBC		Sex	(1) Average age of general population (years)	(2) LE of general population (years)	(3) Average age in PBC (years) (GBD)	(4) LE of at risk population (years) (GBD)
1	Infectious diseases	M	38.5	80.7	28.6	79.6
		F	40.8	84.4	30.2	83.6
2	Cancer	M	38.5	80.7	61.3	83.0
		F	40.8	84.4	52.3	84.7
4	Endocrine	M	38.5	80.7	44.2	81.0
		F	40.8	84.4	50.8	84.7
7	Neurological	M	38.5	80.7	24.8	79.6
		F	40.8	84.4	23.5	83.3
10	Circulatory	M	38.5	80.7	55.4	83.0
		F	40.8	84.4	57.9	86.5
11	Respiratory	M	38.5	80.7	32.1	80.3
		F	40.8	84.4	33.7	84.0
13	Gastrointestinal	M	38.5	80.7	35.8	80.6
		F	40.8	84.4	41.9	84.5
17	Genitourinary	M	38.5	80.7	63.2	83.5
		F	40.8	84.4	47.3	85.6
18 + 19	Maternity and neonates	M	38.5	80.7	3.0	78.7
		F	40.8	84.4	24.1	83.1

F, female; GBD, Global Burden of Disease; M, male.

population, that is the LE for a matched normal population should be higher with fewer deaths above and more below this LE.

Using additional information about age and gender distribution

It is evident that estimates of YLL require some account to be taken of counterfactual deaths. In the absence of routinely available information this requires examination of alternative sources of information which might provide a basis for more credible assumptions about the age and gender distribution of the PBC population than either, the distribution of observed deaths or the general population.[j] The World Health Organization (WHO) Global Burden of Disease (GBD) study, updated in 2008 using 2004 data (see *Addendum 1: data sources* in *Appendix 3* for more details),[k] provides a range of summary health indicators for the UK, which are, in part, based on estimates of the incidence of sequelae associated with different types of disease by age and gender.[l] Therefore, the type of information used by WHO in the GBD study to generate summary estimates for the UK can also be used to improve the assumptions required about the age and gender distribution of the PBC populations. Importantly, at this stage, we do not need to rely on estimates of the absolute size of the at risk population, but only the relative 'share' by age and gender.

The Global Burden of Disease study classifies diseases by U-codes, which are groups of three digit ICD-10 codes (see *Addendum 1: data sources* in *Appendix 3* for details of how U-codes map to ICD-10 codes).[m] As we know which ICD-10 codes contribute to each PBC we can map information from U-codes to PBCs via the ICD-10 codes that contribute to each. The resulting average age and LE for each PBC is reported in columns (3) and (4) of *Table 11* using the information available from GBD in combination with life tables for the general population.

These summary estimates suggest that some of the PBC populations may on average be older than the general population (e.g. cancer, circulatory and genitourinary) or younger (e.g. maternity and neonates, infectious diseases and neurological). However, when trying to interpret these summaries it should be noted that the average age reported in *Table 11* is the average over the ages at which sequelae occur within the ICD-10 codes contributing to the PBC. Therefore, a similar average age can reflect very different age distributions. Some reflect a markedly bimodal distribution (e.g. respiratory, where there is high incidence at very young and older ages), or very different age distributions across the type of diseases that contribute to the PBC. For example PBC 7 (neurological) includes dementia which accounts for the vast majority of the PBC population older than 70 years. However, a greater proportion of the population is in much younger age groups with other conditions, especially migraine (see *Appendix 3, Addendum 1: data sources*). When interpreting these summary estimates it should also be noted that the reported life expectancies are not the life expectancies at the average ages reported in column (3), but the average over the life expectancies for each age group within the contributing ICD-10 codes weighted by the age distribution of sequelae from GBD U-codes.

The implications for net YLL of using these PBC-specific estimates of 'normal' LE are reported in *Table 12*. As expected, the net YLL for those PBC with a LE greater than the general population are higher than those reported in column (5) in *Table 10* (e.g. PBC 10 circulatory and PBC 17 genitourinary, which now has positive net YLL). Similarly, those PBCs with a LE less than the general population have lower net YLL than reported in column (5) in *Table 10* (e.g. PBC 1 infectious diseases and PBC 18 + 19 maternity and neonates, where the effect of a lower LE is more modest as there are no deaths above either of the estimates of LE).

The impact on the cost per life-year threshold of the issues discussed in the *Introduction*, *From mortality to life-years* and *Adjusting life-years for quality-of-life* are summarised in *Table 13* (see *Table 116* in *Appendix 3* for detailed breakdown of changes in spend and YLLs across PBCs).

Using ONS data to calculate YLL in the same way as the published NHS IC figures, but overcoming some of the issues associated with the reporting of mortality at PCT level and the coverage of published estimates of YLL (see *Mortality and years of life lost coverage*), generates similar estimates of a cost per life-year threshold [see *Table 13*, column (1)] to those reported in *Chapter 3*. Calculating YLL in the same

TABLE 12 Net YLL using LE for each PBC

PBC		(1) LE of males (years)	(2) LE of females (years)	Average 2006–8				(7) Net YLL
				(3) Death < LE	(4) Death > LE	(5) YLL	(6) YLG	
1	Infectious diseases	79.6	83.6	3498	3460	58,686	21,724	36,962
2	Cancer	83.0	84.7	101,203	29,607	1,473,733	126,549	1,347,184
4	Endocrine	81.0	84.7	4068	2696	66,283	15,058	51,225
7	Neurological	79.6	83.3	8370	6983	135,686	41,770	93,917
10	Circulatory	83.0	86.5	96,694	63,157	1,102,020	278,251	823,768
11	Respiratory	80.3	84.0	29,549	35,897	298,343	230,313	68,030
13	Gastrointestinal	80.6	84.5	15,824	8323	273,117	45,414	227,703
17	Genitourinary	83.5	85.6	4969	5655	47,229	29,101	18,127
18 + 19	Maternity and neonates	78.7	83.1	226	0	16,801	0	16,801

TABLE 13 Summary of cost per life-year threshold

PBC grouping	Using cut-off in estimating YLL (ONS) (£)		Using net YLL estimates (£)	
	(1) Cut-off of 75 years	(2) Cut-off of LE of the general population	(3) Using LE of the general population	(4) Using LE of the PBC population (GBD)
All big four programmes	10,398	5487	10,421	8080
11 PBCs (with mortality)	20,031	10,660	19,928	15,628
All 23 PBCs (zero health effects for remaining 12 PBCs)	73,697	39,218	73,317	57,497
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	22,639	12,048	22,523	17,663

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

way, but based on the LE of the general population significantly overestimates YLL for the reasons set out in *Life expectancy and years of life lost* so underestimates the cost per life-year threshold [see *Table 13*, column (2)]. Taking account of counterfactual deaths by calculating net YLL based on the LE of the general population [see *Table 13*, column (3)] provides similar estimates to those reported in *Chapter 3*. Assuming that PBC populations have the same age and gender distribution as the general population when the, albeit limited, information that is available suggests otherwise, seems inappropriate. Therefore, our preferred central estimate of the cost per life-year threshold is reported in *Table 13*, column (4). These are lower than those based on the general population, reflecting the impact on net YLL of evidence that the population at risk in some key PBCs (especially PBCs 2 and 10) tend to be older than the general population. In *Summary of cost per life-year estimates* we consider extreme upper and lower bounds that might be placed on this central estimate.

Inferring excess deaths

We have been able to establish a measure of net YLL, which takes account of deaths that would have occurred anyway below a normal LE for the PBC population (i.e. not all deaths observed in a PBC are excess), and that some deaths observed above this LE would not otherwise have occurred at that age

(i.e. some of these deaths are excess). As explained in *Years of life lost and accounting for counterfactual deaths*, net YLL calculated in this way is equivalent to first establishing the number of excess deaths at each age, then calculating YLL for each excess death (based on the LE conditional on the age at which each excess death occurred) and then summing these YLL across all excess deaths (i.e. across all ages). In other words, the estimates of net YLL imply a number of excess deaths required to generate them in each PBC. Therefore, it is possible to solve for the total number of excess deaths based on the net YLL and the average YLL per observed death.[n] The net YLL divided by the average YLL per death provides the number of excess deaths required, which on average will generate the estimated net YLL.[o]

The implied excess deaths associated with net YLL based on the LE of the PBCs [see *Table 12*, column (7)] are reported in *Table 14*. With the exception of PBC 18 + 19, excess deaths are some proportion of total observed deaths in each PBC. The proportion of excess deaths differs by PBC reflecting the distribution of deaths relative to the LE of the PBC.[p] For example, in those PBCs where a large proportion of deaths occur below LE [see *Table 12*, columns (3) and (4)], excess deaths tend to be a greater proportion of the total deaths (e.g. PBC 2, 13 and 10). Where most deaths occur above LE, excess deaths as a proportion of the total deaths tend to be lower (e.g. PBC 1, 11 and 17).

Estimates of net YLL and changes in life-years due to expenditure (see *Tables 12* and *13*) have already accounted for the fact that not all deaths are excess and don't generate YLL. Nevertheless, solving for the number of implied excess deaths associated with these net YLL estimates allows a comparison of the cost per excess and observed PBC death avoided and an examination of the interpretation that can be placed on the life-years expected to be gained from an excess or observed death averted. As only deaths observed in the PBC can be used to estimate the effects of expenditure (excess deaths are not directly observed as they rely on an unobserved counterfactual population and would occur outside the PBC), the outcome elasticities can be interpreted as the proportionate change in observed PBC mortality due to a proportionate change in PBC expenditure. Equally, however, they can also be interpreted as the proportionate effect on excess death due to a proportionate change in expenditure so can be applied to either total observed or total excess deaths.[q]

The cost per excess death and the cost per PBC death averted are reported in *Table 15* (see *Table 119* in *Appendix 3* for a detailed breakdown of changes in spend and excess or PBC deaths across PBCs). The cost per PBC death averted is, of course, significantly lower than the cost per excess death as excess deaths are only a proportion of total deaths (see *Table 14*). Also the cost per PBC death averted is substantially lower than those reported in *Chapter 3* (see *Tables 68* and *69* in *Appendix 2*), as these estimates do not restrict the effects of expenditure to PBC deaths under the age of 75 years.[r] The cost per PBC or excess death

TABLE 14 Excess deaths implied by net YLL

PBC		(1) Net YLL	(2) YLL per observed death	(3) Excess deaths	(4) Total deaths	(5) % excess deaths
1	Infectious diseases	36,962	13.4	2797	6958	40
2	Cancer	1,347,184	14.1	95,715	130,810	73
4	Endocrine	51,225	13.7	3769	6764	56
7	Neurological	93,917	13.7	6909	15,353	45
10	Circulatory	823,768	10.5	79,218	159,851	50
11	Respiratory	68,030	9.2	7386	65,445	11
13	Gastrointestinal	227,703	15.2	15,199	24,147	63
17	Genitourinary	18,127	8.3	2172	10,625	20
18 + 19	Maternity and neonates	16,801	73.9	226	226	100

TABLE 15 Summary of the cost per death averted threshold

PBC grouping	(1) Cost per excess death averted (£)	(2) Cost per PBC death averted (£)
All big four programmes	91,129	32,864
11 PBCs (with mortality)	177,692	64,774
All 23 PBCs (zero health effects for remaining 12 PBCs)	653,748	238,310
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	200,829	73,208

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

averted (or life saved) should not be over interpreted as they are of little direct policy interest because lives are never saved (death is only delayed), and the significance of a death averted depends critically on how long it is averted for (the YLGs, see *Table 13*) and the QoL in which additional years are lived (see *Adjusting life-years for quality-of-life*).

However, establishing the number of excess and PBC deaths averted which are associated with net YLL is useful because it enables an assessment of the number of YLGs associated with each death averted. On average, across all 11 PBCs, each excess death averted is associated with 11.4 YLGs. These are reported for each PBC in *Table 121* in *Appendix 3,* and range from 74.3 years per excess death for PBC 18 + 19 maternity and neonates to 8.3 years for PBC 17 genitourinary. However, clinicians or the evaluative literature cannot distinguish whether or not an observed death is excess. What can be observed is whether or not groups of similar patients with and without access to a treatment survive and for how long. Therefore, it is the life-years associated with each observed death that provide a context that can be interpreted based on experience and evidence of how effective those interventions that could be invested or disinvested intend to be. The average life-years expected to be gained associated with each observed PBC death averted takes account of the fact that some deaths that are avoided in the PBC are not delayed for very long but quickly occur[s] elsewhere and do not generate YLGs (i.e. they were not excess deaths). These are also reported for each PBC in *Table 121* in *Appendix 3* and range from 74.3 years per observed death for PBC 18 + 19 maternity and neonates[t] to 1.0 year for PBC 11 respiratory problems (i.e. the YLL per PBC death are much lower for those PBCs where a small proportion of observed deaths are excess). Each PBC death averted is associated with 4.1 YLGs on average across all 11 PBCs.

Summary of cost per life-year estimates

The sequence of analysis set out above has enabled an examination of the impact of the limitations associated with the incomplete reporting of mortality data at PCT level and incomplete coverage of published YLL estimates. We have also been able to consider effects above the age of 75 years while taking account of that fact that many deaths would have occurred anyway, despite the limited information available about the population at risk within a PBC. The GBD study does provide some information about the age and gender distribution of the population at risk in a PBC so offers some improvement over the other assumptions that would otherwise be required (i.e. that the distribution of age and gender is the same as the general population or follows the distribution of observed deaths). For this reason the cost per life-year threshold in column (4) of *Table 13* and repeated in lines (1)–(4) in *Table 16* are regarded as the central or best estimates given the evidence available and the credibility of alternative assumptions that could be made. As explained in the *Introduction* of this chapter, these are based on the conservative assumption that any health effects of changes in expenditure are restricted to 1 year, which, to some extent, may be offset by the more optimistic assumption any death averted returns the individual to the mortality risk faced by the general population, matched for age and gender.

TABLE 16 Summary of the cost per life-year threshold with upper and lower bounds

PBC grouping	Cost per life-year threshold
Best estimate	
Effect of expenditure on mortality	1 year
YLL per PBC death averted	~4.1[a]
(1) All big four programmes	£8080
(2) 11 PBCs (with mortality)	£15,628
(3) All 23 PBCs (zero health effects for remaining 12 PBCs)	£57,497
(4) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[b]	£17,663
Lower bound	
Effect of expenditure on mortality	Remainder of disease
YLL per PBC death averted	~4.1[a]
(5) All big four programmes	£3846
(6) 11 PBCs (with mortality)	£6106
(7) All 23 PBCs (zero health effects for remaining 12 PBCs)	£22,463
(8) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[b]	£6901
Upper bound	
Effect of expenditure on mortality	1 year
YLL per PBC death averted	2
(9) All big four programmes	£16,432
(10) 11 PBCs (with mortality)	£32,387
(11) All 23 PBCs (zero health effects for remaining 12 PBCs)	£119,155
(12) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[b]	£36,604

a See *Tables 114*, *115* and *118* in *Appendix 3*.
b In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

It does not seem credible to imagine that NHS expenditure has no health effects in the 12 PBCs which do not have sufficient mortality reported at PCT level to estimate outcome elasticities – what is implied by the estimate reported in *Table 16*, line (3). Therefore, it is the estimates reported in *Table 16*, lines (2) and (4) that are of policy interest. The estimate of £15,628 per life-year [see *Table 16*, line (2)] is restricted to the effects of changes in expenditure in the 11 PBCs where outcome elasticities can be estimated. The threshold of £17,663 per life-year uses the estimated health effects of expenditure in these PBC as a surrogate for health effects in the others, that is assuming that the effects that can be observed will be similar to those that cannot. However, no health effects are assigned to PBC 23 (GMS) on the basis that any health effects of this expenditure would be recorded in the other PBCs.[u]

The extreme upper and lower bounds for the cost per life-year thresholds in *Table 16* are based on making the necessary assumptions about duration of health effects and how long a death might be averted optimistic (providing the lower bound for the threshold) or conservative (an upper bound for the threshold). The lower bound [see *Table 16*, lines (5)–(8)] is based on assuming that health effects are not restricted to 1 year but apply to the whole of the remaining disease duration of the population at risk in PBCs during the expenditure year.[v] Although this combines optimistic assumptions, it is possible, indeed likely, that at least some expenditure may have effects on the health outcomes of future patients who are not currently part of the population at risk in a PBC (e.g. investments or disinvestment in prevention will

have an impact on populations that are incident to PBCs in the future). Such effects are not captured in any of the estimates presented in this chapter so all are conservative with respect to this type of health effect of changes in expenditure.

The upper bound [see *Table 16*, lines (9)–(12)] is based on the combination of assuming that health effects are restricted to 1 year for the population currently at risk and that any death averted is only averted for the minimum duration consistent with the mortality data. The econometrics work used the average of 3 years of mortality (2006–8), so the estimated outcome elasticities are based on differences in mortality that remain after averaging over 3 years. Therefore, the estimated effects are based on differences in observed PBC deaths that must have been sustained, on average, for more than a minimum of 2 years.[w]

Adjusting life-years for quality-of-life

The central or best estimates of the cost per life-year threshold, which were presented in *Table 16*, lines (2) and (4), take no account of the health-related QoL in which years of life, expected to be gained or lost through changes in expenditure, are likely to be lived. Even if attention is restricted to the direct health consequences of changes in mortality, estimates of the cost per life-year will tend to overestimate the effects of changes in expenditure (i.e. underestimate the threshold) compared with a more complete measure of health that accounts for the quality in which the years of life are expected to be lived. In this section we examine the ways in which the life-years reported in *From mortality to life-years* can be adjusted for quality, taking account of information that is available about (i) how QoL differs by age and gender (see *Quality of life based on the general population*); and (ii) how the quality-of-life-years associated with mortality changes might be affected by the types of diseases that make up each PBC (see *Adjusting age-related quality-of-life for disease decrements*). Throughout, we continue to take account of counterfactual deaths in the way described in *Years of life lost and accounting for counterfactual deaths* by making the adjustment for quality to the life-years associated with every observed death before calculating a quality-adjusted net YLL. The implications for a cost per QALY threshold that only accounts for the health effects of mortality changes are presented in *Summary of the cost per quality-adjusted life-year threshold based only on mortality effects*. In *Including quality-of-life effects during disease* we explore the ways in which the likely direct effects of expenditure on QoL (other than through mortality) might also be taken into account.

Quality of life based on the general population

The most commonly used metric of health-related QoL in the UK is European Quality of Life-5 Dimensions (EQ-5D),[91] which is specified in the NICE reference case for methods of technology appraisal.[3] This metric has five dimensions of quality each with three possible levels. Each of these 243 possible health states is valued relative to a score of one, which represents full or best imaginable health (the best score across all five dimensions), and a score of zero, which represents death, based on a representative sample of the UK population.[92] Therefore, insofar as the years of life expected to be gained (or lost) through changes in expenditure would be lived in this state of full health, the cost per life-year thresholds reported in *Table 16* would also be the cost per QALY thresholds, albeit ones that only account for the health effects of mortality changes. However, unsurprisingly, there is good evidence that, on average, the general population is not in this state of full health. Therefore, the QoL score associated with the health states experienced by the general population are less than 1, decline with age and differ by gender. These QoL 'norms' for the general population by age and gender are illustrated in *Figure 3* based on an analysis of data from the Health Survey for England (HSE).[x]

These QoL norms can be applied to the YLL associated with all observed deaths in each PBC, taking account of gender and age at death. The results are reported in columns (4)–(6) of *Table 17*. There are two effects of adjusting life-years for quality: (i) as QoL norms are always < 1 the adjusted YLL and YLG are always lower than the unadjusted values in columns (1) and (2) (previously reported in *Table 12*); and (ii) deaths above LE are necessarily at older ages with poorer QoL norms than those below, so the difference between adjusted and unadjusted values is greater for YLG than YLL. The overall effect of

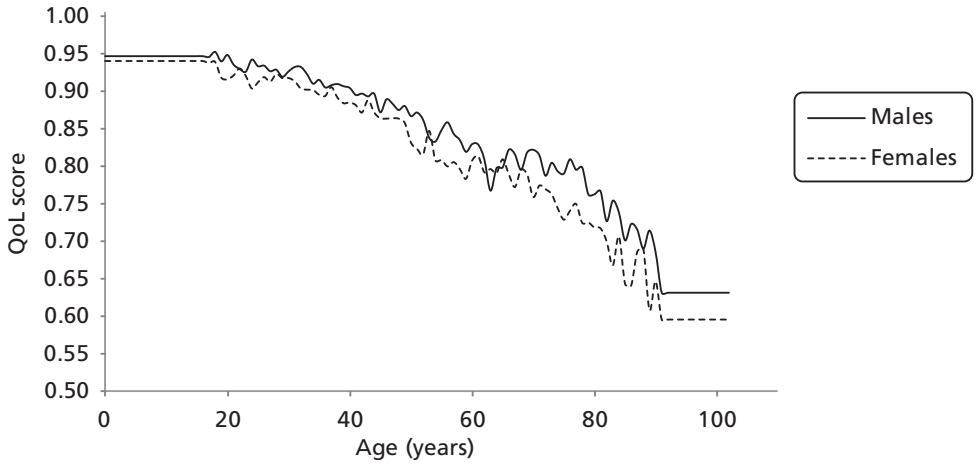

FIGURE 3 Quality of life for the general population by age and gender. Pooled QoL estimates provided by personal communication with Dr Anju Keetharuth, University of Sheffield, 2013.

TABLE 17 Net YLL adjusted for the QoL 'norms'

		Unadjusted life-years			QALYs		
PBC		(1) YLL	(2) YLG	(3) Net YLL	(4) YLL	(5) YLG	(6) Net YLL
1	Infectious diseases	58,686	21,724	36,962	47,481	14,618	32,864
2	Cancer	1,473,733	126,549	1,347,184	1,143,445	84,036	1,059,409
4	Endocrine	66,283	15,058	51,225	52,856	9973	42,883
7	Neurological	135,686	41,770	93,917	109,349	28,262	81,087
10	Circulatory	1,102,020	278,251	823,768	848,046	183,330	664,717
11	Respiratory	298,343	230,313	68,030	231,578	154,743	76,835
13	Gastrointestinal	273,117	45,414	227,703	216,256	30,277	185,979
17	Genitourinary	47,229	29,101	18,127	35,929	18,947	16,982
18 + 19	Maternity and neonates	16,801	0	16,801	14,568	0	14,568

quality adjustment on net YLL is the balance of these two effects. The overall effect of quality adjustment is to reduce the net YLL [compare *Table 17*, columns (3) and (6)].[y]

The quality adjusted net YLL figures in *Table 17*, column (6) suggests that the health effects of mortality are lower than when relying only on unadjusted life-years in *From mortality to life-years*. Therefore the health effects of changes in expenditure on this more complete measure of health are lower. The implications of these adjustments on a cost per QALY threshold that only accounts for the direct health effects of mortality are reported in *Table 18*. As expected the cost per QALY threshold based on adjusting the YLGs or lost [see *Table 18*, column (2)] is higher than a threshold based on unadjusted life-years [see *Table 18*, column (1) and previously reported in *Table 16*].

Adjusting age-related quality-of-life for disease decrements

Adjusting life-years for age- and gender-related QoL norms assumes that any YLG through a change in expenditure would be lived in a similar QoL to the general population. It is possible, however, that patients benefiting from reduced mortality may, nevertheless, continue to be affected by the type of diseases that make up each PBC and experience the QoL associated with the original disease.

The HODaR[93] provides over 30,000 observations of EQ-5D measures of QoL by ICD-10 code and the age and gender of the patients in the sample (see *Appendix 3, Addendum 1: data sources*). Although this is a

TABLE 18 Summary of cost per QALY threshold based on population norms and mortality effects

PBC grouping	(1) Cost per life-year threshold (£)	(2) Cost per QALY threshold (population norms) (£)
All big four programmes	8080	9631
11 PBCs (with mortality)	15,628	18,622
All 23 PBCs[a]	17,663	21,047

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal, except GMS.

rich UK data set, there were a limited number of observations for some of the less common ICD-10 codes. For this reason HODaR was supplemented with information from the Medical Expenditure Panel Survey (MEPS)[94] which also provides EQ-5D by ICD-10 and reports the average age of respondents (see *Appendix 3, Addendum 1: data sources*). These data provided a means of estimating the QoL associated with each ICD-10 code at the average age of respondents in the pooled sample.[z] The QoL associated with each PBC can be expressed as an average of the QoL associated with its component ICD-10 codes.[aa] The QoL effects of being in each PBC can then be expressed as a disease-related decrement compared with the population norms at the same age (see *Table 129* in *Appendix 3*). This is illustrated for PBC 1 (infectious disease) in *Figure 4*, where the weighted average of QoL scores across the component ICD-10 codes was 0.667, at an average age average age of 54 years for male respondents. As the QoL norms for males age 54 years is 0.859 this suggests a decrement associated with membership of PBC 1 of 0.192, which can then be applied to QoL norms by age.[ab]

Quality-of-life norms adjusted for disease-related decrements can be applied to the YLL associated with observed deaths in each PBC, taking account of gender and age at death in the same way as in *Quality of life based on the general population*.[ac] The results are reported in columns (4)–(6) of *Table 19*. The overall effect of quality adjustment that also applies a disease-related decrement is to reduce the net YLL to a greater extent than adjustment with population norms alone [compare column (6) in *Table 19* with column (6) in *Table 17*].

It should be noted that combining QoL adjustments for both population norms and disease-related decrements assumes that any YLGs due to a reduction in mortality will be lived in the diseased state until LE (i.e. that all diseases are not just chronic but disease duration is lifelong). Inevitably this assumption means that the health effects of changes in mortality will be reduced. Consequently, the cost per QALY threshold reported in *Table 20*, column (2) will be higher than adjusting YLGs for population norms in *Table 18*.

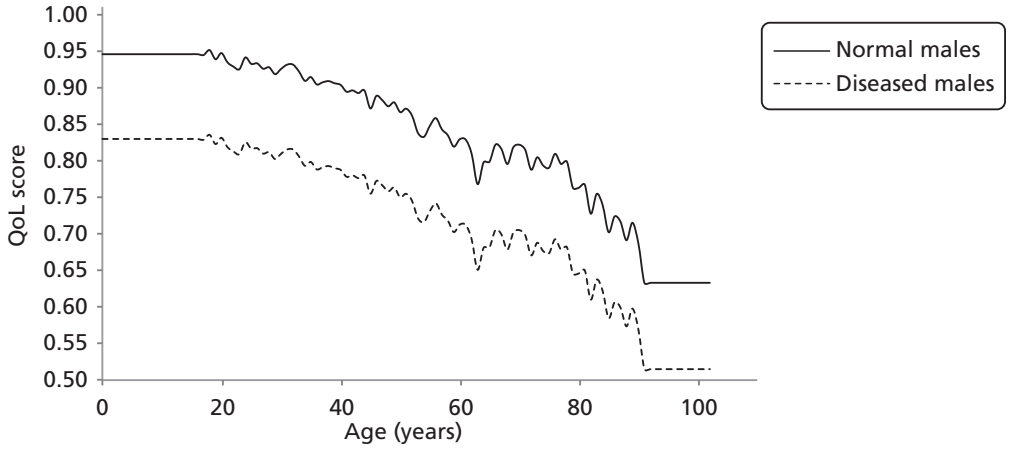

FIGURE 4 Quality of life for males in PBC 1 (infectious disease) and the general population by age.

TABLE 19 Net YLL adjusted for disease- and age-related QoL

PBC		Unadjusted life-years			QALYs		
		(1) YLL	(2) YLG	(3) Net YLL	(4) YLL	(5) YLG	(6) Net YLL
1	Infectious diseases	58,686	21,724	36,962	37,055	10,793	26,262
2	Cancer	1,473,733	126,549	1,347,184	955,690	67,930	887,760
4	Endocrine	66,283	15,058	51,225	43,394	7844	35,550
7	Neurological	135,686	41,770	93,917	68,893	15,842	53,050
10	Circulatory	1,102,020	278,251	823,768	656,145	135,241	520,905
11	Respiratory	298,343	230,313	68,030	169,269	106,505	62,764
13	Gastrointestinal	273,117	45,414	227,703	163,593	21,677	141,916
17	Genitourinary	47,229	29,101	18,127	29,749	15,152	14,598
18 + 19	Maternity and neonates	16,801	0	16,801	13,662	0	13,662

TABLE 20 Summary of cost per QALY threshold based on disease-related decrements

PBC grouping	(1) Cost per life-year threshold (£)	(2) Cost per QALY threshold (disease-related decrements) (£)
All big four programmes	8080	12,109
11 PBCs (with mortality)	15,628	23,395
All 23 PBCs[a]	17,663	26,441

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal, except GMS.

Summary of the cost per quality-adjusted life-year threshold based only on mortality effects

The analysis to this point is summarised in *Table 21*. The three estimates of a cost per QALY threshold are based on assuming that each YLG is either lived in full health [see *Table 21*, column (1), equal to the cost per life-year estimates in *Table 16*]; lived in a QoL that reflects age and gender norms of the general population [see *Table 21*, column (2)]; or lived in a QoL that reflects the original disease state [see *Table 21*, column (3)].

Assuming that YLGs are lived in full health is not credible and should be regarded as an underestimate of the threshold, given what is known about QoL norms for the general population (see *Figure 3*). Equally, assuming that all YLGs are lived in the QoL of the original disease state does not seem credible either and is likely to overestimate the threshold as it assumes that all disease is not only chronic but lifelong and all life-years would be lived in the diseased state until death.[ad] Although adjusting YLGs for the QoL of the general population, taking account of age and gender [see *Table 21*, column (2)], is likely to underestimate a cost per QALY threshold based only on mortality effects, it probably represents the 'best' of the three alternative estimates available at this stage of the analysis (see *Using estimates of the QALY burden of disease* for how analysis based on measures of QALY burden allows this assumption to be relaxed).[ae] The lower and upper bounds are based on combining optimistic and pessimistic assumptions about the duration of health effects and how long a death might be averted as described in *Summary of cost per life-year estimates*.

TABLE 21 Summary of QALY threshold estimates based only on mortality effects

PBC grouping	(1) QoL score = 1	(2) QoL norm	(3) QoL diseased
Best estimate			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per PBC death averted	~4.1[a]	~4.1[a]	~4.1[a]
QALYs per death averted	~4.1	~3.5	~2.8
(1) All big four programmes	£8080	£9631	£12,109
(2) 11 PBCs (with mortality)	£15,628	£18,622	£23,395
(3) All 23 PBCs[b]	£17,663	£21,047	£26,441
Lower bound			
Effect of expenditure on mortality	*Remainder of disease*	*Remainder of disease*	*Remainder of disease*
YLL per PBC death averted	~4.1[a]	~4.1[a]	~4.1[a]
QALYs per death averted	~4.1	~3.5	~2.8
(4) All big four programmes	£3846	£4252	£5319
(5) 11 PBCs (with mortality)	£6106	£6852	£8568
(6) All 23 PBCs[b]	£6901	£7744	£9683
Upper bound			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per PBC death averted	2	2	2
QALYs per death averted	2	~1.9	~1.5
(7) All big four programmes	£16,432	£17,456	£21,747
(8) 11 PBCs (with mortality)	£32,387	£34,492	£42,967
(9) All 23 PBCs[b]	£36,604	£38,983	£48,561

a See *Tables 114*, *115* and *118* in *Appendix 3*.
b In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal, except GMS.

However, it should be noted that these cost per QALY thresholds only account for the direct health effects of changes in mortality due to changes in expenditure. Insofar as much, or at least some, of NHS activity and expenditure is intended to improve QoL, not just mortality, then these estimates will underestimate total health effects and overestimate a cost per QALY threshold based on a more complete measure of possible health effects. In *Including quality-of-life effects during disease* we explore the ways in which the likely effects of expenditure on QoL (other than through mortality) might also be taken into account.

Including quality-of-life effects during disease

The cost per QALY thresholds presented in *Adjusting life-years for quality-of-life* only account for the health (QALY) effects of changes in mortality due to changes in expenditure. It does not seem credible to suppose that all NHS activity and expenditure only influences mortality with no effect on the QoL while alive and experiencing a disease. Insofar as changes in NHS expenditure will also affect QoL as well as mortality then total health effects will be underestimated and the thresholds presented in *Table 21* will overestimate the cost per QALY threshold. In this section we explore ways to also take account of those effects on health not directly associated with mortality and life-year effects (i.e. the 'pure' QoL effects) to estimate an overall cost per QALY threshold.

The routine reporting of QoL outcomes is increasingly available at PCT level (see *Addendum 1: data sources* in *Appendix 3* for a description of these data). In principle, the variation in such measures of outcome across PCTs could be used to estimate outcome elasticities for QoL rather than mortality effects using similar econometric methods to those described in *Chapter 3* (see *Application of method to other non-mortality-based outcome indicators* in *Appendix 2* for the results of an exploratory econometric analysis of these data). However, the currently limited coverage of routine reporting of these outcomes means that it is not feasible to estimate QoL effects across all the PBCs using these data. In *Chapter 5, Future research and improving estimates of the threshold* we discuss how these data might be used to improve estimates of the threshold as the coverage and routine reporting of QoL outcomes improves, and how the analysis presented in *Chapter 5, Which programme budget categories matter most?,* might help prioritise reporting in particular areas (i.e. those PBCs and ICD-10 codes that have the greatest influence on estimates of the threshold).

Here we explore how estimates of effects of expenditure that can be observed (i.e. on mortality) can be used to infer the likely effects on what cannot be directly observed (QoL), rather than making extreme assumptions that are not credible (e.g. assuming that changes in expenditure will have no effects on QoL outcomes).

In *Using ratios of quality-adjusted life-years to years of life lost* we use three alternative estimates of the ratio of QALYs to life-years lost due to different types of disease as a means of inferring the change in QALYs that is likely to be associated with the estimated change in YLL (i.e. applying the total QALYs lost associated with each YLL with disease). This is consistent with regarding the estimates of the mortality and life-year effects as a surrogate for a more complete measure of the health effects of a change in expenditure.

However, these ratios of QALYs lost to life-years lost due to disease in those PBCs where outcome elasticities could not be estimated cannot inform estimates of the threshold (there are no estimated life-year effects with which to apply the ratios). Nonetheless, the sources of information on which ratios are based also provides much of the information required to calculate the QALY burden of disease in these areas, which can be used to inform estimates of the threshold. Therefore, in *Using estimates of the quality-adjusted life-years burden of disease* we use estimates of the QALY burden of disease, infer a proportionate effect on burden from the estimated effects on life-years, and then apply this proportionate effect to the measures of QALY burden for all the other PBCs. In this way we can use all the information available about the mortality and QoL effects of the different types of disease that make up each PBC, including those where mortality-based outcome elasticities are not available.

Using ratios of quality-adjusted life-years to years of life lost

The ratio of the total QALYs to YLL due to a disease indicates the number of QALYs associated with each YLL. Therefore, any change in YLL is likely to generate a number of QALYs indicated by the ratio – if it is reasonable to interpret the estimated effects on mortality and life-years as a surrogate for a more complete measure of total health effects. For example, a disease with a ratio > 1 suggests that each YLL across the at risk population is associated with more than 1 QALY (i.e. where there are significant QoL effects while experiencing the disease).[af] Therefore, a change in expenditure that leads to 1 YLG in this type of disease may be expected to generate > 1 QALY and a greater QALY effect than the same life-year effects in a disease where this ratio is < 1 (i.e. where most of the effect of disease is on mortality rather than QoL). Therefore, information which allows these ratios to be estimated for the diseases that make up each PBC provides a means of accounting for the likely effect on QoL other than through effects on mortality.

To understand the differences between the three ratios presented below it is useful to regard the total QALY lost to YLL ratio (R) for a particular disease as the sum of two ratios: (i) the QALYs lost due to premature death to YLL ratio (R_{death});[ag] and (ii) the QALYs lost during disease (while alive) to YLL ratio (R_{alive}) (see *Using ratios of quality-adjusted life-year to years of life lost* in *Appendix 3* for more detailed explanation).

Disability-adjusted life-year to years of life lost ratios

The WHO GBD study provides UK-specific estimates of the years of life lived with disability (YLD) and the YLL due to different types of disease (classified by U-codes that can be mapped to ICD-10, see *From mortality to life-years* and *Addendum 1: data sources* in *Appendix 3*). The GBD study uses disability-adjusted life-years (DALYs) as a measure of the burden of disease. This DALY measure has two components: (i) the YLD, which incorporates weights (between 0 and 1) to reflect the scale of disability experienced each year and the number of YLDs over the durations of disease; and (ii) the YLL. The total DALY associated with a disease is simply YLL + YLD. Therefore, the DALY to YLL ratio is (YLL + YLD)/YLL or equivalently YLL/YLL + YLD/YLL. As the first term (YLL/YLL = R_{death}) must equal 1 and the second (R_{alive} = YLD/YLL) must be ≥ 0, a ratio based on DALYs must necessarily be bounded below by 1. This is illustrated in *Table 22* for four different types of diseases (classified by U-codes) which reflect diseases where mortality is the major component (e.g. U016) and where the impact of disease on the QoL while alive is the major component (e.g. U141).

Adjusting disability-adjusted life-years for quality-of-life norms

The use of DALY ratios bounded below by 1 essentially assumes that YLL would have otherwise been lived in a state of full health. As was discussed in *Quality of life based on the general population* this is not credible given information available about the QoL in the general population (see *Figure 3*). It would lead to over estimating the QALYs associated with mortality and life-year effects and underestimating the cost per QALY threshold. Therefore, it is important to adjust these DALY ratios for the QoL norms by age and gender in the same way as described in *Quality of life based on the general population*. The effect of this adjustment[ah] is illustrated in *Table 23*. Now those types of disease where mortality rather than QoL with the disease is the major component can have ratios < 1. Indeed, the first term of these ratios (R_{death}) is consistent with, and is implied by, the analysis in *Quality of life based on the general population* where the ratio of quality-adjusted net YLL to unadjusted net YLL represents this ratio on average for each PBC.

TABLE 22 Examples of DALY to YLL ratios

U-code	DALY ratios	($R_{death} + R_{alive}$)
U037 (other infectious diseases)	1.23	(1 + 0.23)
U016 (tetanus)	1.00	(1 + 0)[a]
U061 (mouth and oropharynx cancers)	1.05	(1 + 0.05)
U141 (spina bifida)	2.34	(1 + 1.34)[b]

a Given the short disease duration, it is only mortality effects that contribute to the ratio.
b QoL effects during disease contribute significantly to estimates of the ratio.

TABLE 23 Examples of modified DALY to YLL ratios

U-code	Modified DALY ratios	($R_{death} + R_{alive}$)
U037 (other infectious diseases)	1.01	(0.78 + 0.23)
U016 (tetanus)	0.78	(0.78 + 0)
U061 (mouth and oropharynx cancers)	0.83	(0.78 + 0.05)
U141 (spina bifida)	2.18	(0.85 + 1.34)

Using quality-of-life estimates (based on Health Outcomes Data Repository and Medical Expenditure Panel Survey data)

The disability weights used in the DALY measure are not based on the same description of health states as the EQ-5D measure, nor are the weights based on a representative sample of the UK population responding to choice-based elicitation questions. EQ-5D-based QoL decrements (adjustments to age-related QoL norms) associated with different types of disease can be estimated from HODaR and MEPS data (previously described in *Adjusting age-related quality-of-life for disease decrements*).[ai] These disease-related QoL decrements be can be calculated for each U-code (based on the contributing ICD-10 codes) so can be used to replace the DALY disability weights in R_{alive} reported in *Tables 22* and *23*.[aj] This final adjustment is illustrated in *Table 24* and turns, what were originally, DALY ratios into EQ-5D QALY ratios.[ak] For these reasons we regard the QALY to YLL ratios rather than DALY or modified DALY ratios as the preferred basis of estimating a cost per QALY threshold that provides a more complete picture of the likely health effects of changes in expenditure.

Allocating effects at programme budget category level to *International Classification of Diseases* codes

Tables 22–24 illustrate how QALY ratios can be calculated for and differ by U-code.[al] Unsurprisingly, these ratios differ across the type of diseases that make up each PBC (see *Table 147* in *Appendix 3*). When using this information to estimate a cost per QALY threshold the mortality and life-year effects observed at PBC level must be allocated in some way to the component ICD-10 codes before ratios are applied to life-year effects and the resulting QALY effects are summed across all the contributing ICD-10 codes.[am] For this reason it is important to consider how other information might inform the different ways in which the effects observed at PBC level might be generated by the distribution of impacts at ICD-10 level (i.e. where investment or disinvestment is likely to occur within the PBC and, therefore, which ICD-10 codes are likely to contribute most to overall health effects).

An important and complementary element to the econometric analysis of routinely reported information at PBC level was to investigate whether or not other information, commonly available at a local level within the NHS, might provide a useful indication of where, within a PBC, investment or disinvestment is more likely across the NHS. The details of this investigation are reported in *Addendum 2: the role of data on local NHS decisions* in *Appendix 3*. The review of local data sources suggested that there are very few routinely collected data on investment and disinvestment by local NHS organisations beyond the high-level aggregate data on spending by PBC which are used in the econometric analysis. Although more disaggregated data on spending decisions about specific services relevant to particular ICD-10 codes could in principle be acquired through additional primary research (surveys or freedom of information requests), this would be costly and with a risk that information acquired in this way may not be complete, consistent or representative.

In the absence of useful information at a local level it is possible to assume that a change in PBC expenditure will be allocated equally (on a per-patient basis) across the component ICD-10 codes (i.e. any investment or disinvestment is equally likely across the population at risk within the PBC). Hospital Episode Statistics (HES) (see *Addendum 1: data sources* in *Appendix 3*) provides information about the costs associated with each ICD-10 code by PCT so it is possible to establish which ICD-10 codes contribute most

TABLE 24 Examples of QALY to YLL ratios (HODaR and MEPS)

U-code	QALY ratios (HODaR and MEPS)	($R_{death} + R_{alive}$)
U037 (other infectious diseases)	1.37	(0.78 + 0.60)
U016 (tetanus)	0.78	(0.78 + 0)
U061 (mouth and oropharynx cancers)	0.80	(0.78 + 0.02)
U141 (spina bifida)	1.88	(0.85 + 1.03)

to the variability in HES costs within a PBC across PCTs. Those that contribute most to this variance might be expected to be more likely to have been subject to differential investment or disinvestment across PCTs.[an]

There are differences in relative weight assigned to ICD-10 code based on the size of the population or its contribution to variance in HES costs. If investment or disinvestment within a PBC tends to focus on ICD-10 codes representing areas of marginal value, the health effects of a change in PBC expenditure may be overestimated and a cost per QALY threshold underestimated when allocating effects equally across the population at risk within each PBC. However, weighting ICD-10 codes based on HES data is likely to favour those ICD-10 codes which represent more severe disease requiring more hospital care. This may over represent ICD-10 codes with lower QALY to YLL ratios if mortality effects tend to be a major component of these types of disease and may be conservative with respect to the health effects of changes in expenditure.

The implications for a cost per QALY threshold that uses the estimated mortality and life-year effects as a surrogate for a more complete measure of the likely health effects (i.e. that includes QoL as well as QALY effects) is summarised in *Table 25*. These results use the contribution to variance in HES costs to 'weight' the different ICD-10 codes within a PBC (when allocating the life-year effects), before applying the QALY ratios associated with each ICD-10 code (see *Table 143* in *Appendix 3*).

The QALY to YLL ratio implied by this analysis for all 11 PBCs with outcome elasticities is 1.52, which suggests that every (unadjusted) life-year is associated with 1.52 QALYs on average across these PBCs. However, this implied QALY ratio differs across these PBCs, ranging from 0.79 in PBC 2 to 15.05 in PBC 18 + 19 (see *Table 145* in *Appendix 3*). As all the analysis in this section seeks to use the estimated mortality and life-year effects as a surrogate for a more complete measure of likely health effects, it is the cost per QALY threshold for all 23 PBCs that is most relevant. As expected, this threshold (£11,638) is lower than a cost per QALY threshold based only the QoL adjusted YLL effects (£21,047 in *Table 21* that assumes no effects of NHS expenditure on QoL itself). This difference gives some indication of the relative importance of QALY effects due to avoidance of premature death and the QALY effects of avoiding disability during disease.

Table 26 reports how the estimated QALY effects for each PBC can be decomposed into that part associated with life-year effects and that part associated with 'pure' QoL effects. These results appear credible for the first 11 PBCs, where those for which mortality is the major concern have a much greater share of total QALY effects associated with avoidance of premature death (e.g. PBC 2 and PBC 10) compared with those where QoL is the major concern (e.g. PBC 7).[ao]

The ratios of QALYs to YLL due to disease in those PBCs where outcome elasticities could not be estimated cannot be used to inform estimates of the threshold because there are no estimated life-year effects with which to apply the ratios. Therefore, as in previous sections, the estimated effect of expenditure on health for the 11 PBCs with outcome elasticities is applied to the estimated changes in PBC expenditure for the

TABLE 25 Summary of the QALY threshold using QALY to YLL ratios

PBC grouping	(1) DALY ratios (£)	(2) Modified DALY ratios (£)	(3) QALY ratios (HODaR and MEPS) (£)
All big four programmes	5402	6419	5990
11 PBCs (with mortality)	9958	11,718	10,297
All 23 PBCs	11,254	13,244	11,638[a]

a Preferred analysis.

TABLE 26 Decomposing estimated QALY effects by PBC

PBC		QALY change (total)	QALY change (death)	% QALY gained	
				Due to avoidance of premature death	Due to avoidance of disability while alive
2	Cancer	1699	1641	97	3
10	Circulatory	6713	4856	72	28
11	Respiratory	3215	923	29	71
13	Gastrointestinal	3605	1193	33	67
1	Infectious diseases	27	11	40	60
4	Endocrine	2036	323	16	84
7	Neurological	342	52	15	85
17	Genitourinary	12	6	52	48
16	Trauma and injuries	0	0	N/A	N/A
18 + 19	Maternity and neonates	273	15	6	94
3	Disorders of blood	1087	547	50	50
5	Mental health	19,828	9979	50	50
6	Learning disability	2990	1505	50	50
8	Problems of vision	2348	1181	50	50
9	Problems of hearing	621	313	50	50
12	Dental problems	2282	1148	50	50
14	Skin	1021	514	50	50
15	Musculoskeletal	1469	739	50	50
20	Poisoning and adverse events	426	215	50	50
21	Healthy individuals	1781	896	50	50
22	Social care needs	6566	3304	50	50
23	Other	0	0	N/A	N/A

N/A, not applicable.

other 12 PBCs (excluding GMS for the reasons given in *From mortality to life-years*), i.e. assuming that the health effects that can be observed from a change in expenditure will be similar to those that cannot. However, the use of QALY ratios also implies that the share of total health effects between QALY effects and that part associated with 'pure' QoL effects are also similar to those PBC with estimated outcome elasticities. Summing the different types of health effects across these 11 PBCs suggests that 50% is due to avoidance of premature death and 50% is due to avoidance of disability. This is clearly not credible when applied to the other PBCs. For example, to mental health, vision and hearing are likely to have a much greater share of total health effects associated with QoL effects and very little associated with premature mortality.

The problem is that using QALY to YLL ratios means that much of the information that is available about the other 12 PBCs cannot be used to inform the estimates of the cost per QALY threshold. Fortunately, the sources of information on which ratios are based also provide much of the information required to calculate the QALY burden of disease in these areas. *Using estimates of the quality-adjusted*

life-year burden of disease explores how measures of burden can be used to estimate a cost per QALY threshold that captures the likely effects of a change in expenditure on all aspects of health while using all the information that is available about all the PBCs.

Using estimates of the quality-adjusted life-year burden of disease

In this section we use estimates of the QALY burden of disease to infer QALY effects in those PBCs where the mortality effects of changes in expenditure can be observed and then extrapolate the estimated proportionate effects to those PBCs where the health effects of changes in expenditure cannot be observed. The estimated proportionate effect of change in expenditure on the life-year burden of disease in the 11 PBCs where mortality-based outcome elasticities could be estimated are applied to measures of QALY burden in each of these PBCs (i.e. effects on the mortality burden of disease are used as a surrogate for effects on QALY burden). The proportionate effect on burden of disease due to the change in expenditure across these PBCs can then be applied to measures of QALY burden in the other 11 PBCs where mortality effects could not be estimated (i.e. the observed effects of changes in expenditure on burden of disease is extrapolated to the other PBCs where health effects cannot be observed). In this way we can use all the information available about the mortality and QoL effects of the different types of disease that make up each PBC, particularly those where mortality-based outcome elasticities are not available. Applying a proportionate effect to measures of QALY burden of disease is equivalent to assuming that any effects on life-years are lived at a QoL that reflects a proportionate improvement to the QoL with disease.[ap] It also allows QoL effects of changes in expenditure to be included; also based on proportionate improvement in the QoL with disease.

Previously in *Chapter 3* and *From mortality to life-years*, *Adjusting life-years for quality-of-life* and *Using ratios of quality-adjusted life-years to years of life lost*, expenditure elasticities were not estimated for the other 11 PBCs where outcome elasticities could not be estimated because the same health effect of changes in expenditure was assumed (i.e. it did not matter how changes in expenditure was allocated between them). However, in this section it does matter how the remaining change in expenditure is allocated between the other 11 PBCs as they have different QALY burdens so different implied health effects of expenditure. Therefore, expenditure elasticities are estimated for all 23 PBCs (see column 2 of *Table 108* in *Appendix 3*). However, it is not possible to estimate expenditure equations for all 23 PBCs simultaneously (see *Chapter 5, Future research and improving estimates of the threshold*), so the 23 independently-estimated expenditure elasticities do not account for all of the change in overall spend (i.e. the sum of changes in PBC expenditure based on the estimated PBC expenditure elasticities accounts for a $< 1\%$ change in total spend). This remaining change in total spend is allocated between all 23 PBCs reflecting their relative share of changes in expenditure based on their estimated expenditure elasticities [see column (4) of *Table 108* in *Appendix 3*].[aq]

The total QALY burden of disease for the population with disease in a particular year includes (i) the quality-adjusted YLL due to all the disease-related mortality that could occur in this population over their remaining duration of disease; and (ii) the reduction in QoL while alive also for their remaining disease duration. However, applying the estimated proportionate effects on mortality and life-years to such a measure of total burden would provide an estimate of the effects of a change in expenditure, not just in 1 year, but in all the remaining years of disease for the population at risk in that year. Recall from *From mortality to life-years* that we have adopted the conservative assumption that changes in expenditure will only have health effects in 1 year for the population with disease in that year. Therefore it is not a measure of total burden that is required, but a measure of the QALY burden of disease during 1 year for the population with disease (prevalent and incident) in that year. The estimated outcome elasticities can then be appropriately applied to this measure of burden.[ar]

The information from GBD used to derive QALY ratios in *Using ratios of quality-adjusted life-years to years of life lost* includes information about the YLL and duration of disease for those incident to a U-code [i.e. the measure of QALY burden from the information included in the ratios is a measure of the total burden of the disease, but only for the population that is incident (rather than the total population with

disease) in 1 year]. Assuming that incidence is stable over the disease duration, this is also equivalent to the QALY burden of disease during 1 year for the population with disease (i.e. those that are incident and prevalent) in that year.[as]

However, in moving from ratios to absolute measures of burden it becomes more important to examine and then adjust for any inconsistency between information about YLL and size of the incident population from GBD (which is available by U-codes and can be mapped to ICD-10 codes), and the information about net YLL and observed deaths for each PBC based on ONS data as described in *Inferring excess deaths* (see *Table 146* in *Appendix 3*).[at]

The implications for the cost per QALY threshold of using information about the QALY burden of disease for all PBCs rather than QALY ratios for those where an outcome elasticity can be estimated are reported in *Table 27*. The QALY effects of a change in PBC expenditure are a weighted average of the QALY effects within each of the ICD-10 codes that contribute to the PBC. The figures reported in *Table 27*, column (2) are based on weighing the effects at ICD-10 level by the proportion of the total PBC population within each contributing ICD-10 code, rather than the contribution to variance in HES costs.[au]

The cost per QALY threshold for the 11 PBCs with outcome elasticities is lower using a measure of QALY burden (£5128) rather than the QALY ratios (£10,297) described in *Mortality and years of life lost*. This is in part because GBD calculates YLL in the same way as published NHS IC figures and so will tend to overestimate a net YLL which accounts for counterfactual deaths (see *Years of life lost and accounting for counterfactual deaths*). This will make little difference to the first term in the QALY ratio (R_{death}) used in *Mortality and years of life lost coverage* as an overestimate of YLL affects both denominator and numerator of the ratio. However, the second term (R_{alive}) is likely to be underestimated. Therefore the ratios used in *Using ratios of quality-adjusted life-years to years of life lost* will tend to underestimate the QALY effects of expenditure and overestimate the cost per QALY threshold (see *Table 27*). We are able to adjust the GBD-based measure of QALY burden for this overestimation of net YLL in calculating the QALY threshold reported in *Table 27*, column (2).[av]

As the purpose of this section is to use the estimated mortality and life-year effects as a surrogate for a more complete measure of likely health effects, it is the cost per QALY threshold for all 23 PBCs that is of most relevance. The cost per QALY threshold for all 23 PBCs is based on applying the proportionate effects on the QALY burden of disease, based on the observed effects of changes in expenditure on mortality in the 11 PBCs with outcome elasticities,[aw] to the QALY burden of disease in the other PBCs. This generates a higher cost per QALY threshold (£10,187) than the one based only on the 11 PBCs with outcome elasticities (£5128). The reason is that the QALY burden of disease in the other PBCs is, in general, lower than the QALY burden of disease across those PBCs where outcome elasticities can be estimated (see *Table 147* in *Appendix 3*). Therefore, applying the same proportionate effects to a lower QALY burden generates a smaller health effect of a change in expenditure.[ax]

TABLE 27 Summary of the cost per QALY threshold

	Cost per QALY gained (£)[a]	
PBC grouping	(1) QALY ratios (HODaR and MEPS)	(2) QALY burden (HODaR and MEPS)
All big four programmes	5990	3036
11 PBCs (with mortality)	10,297	5128
All 23 PBCs	11,638	10,187[a]

a Preferred analysis.

In essence the difference between the estimates in *Table 27* is that in column (1) the absolute effect on health associated with an absolute change in expenditure is extrapolated to the other PBCs, whereas in column (2) it is the relative effect on health of an absolute change in expenditure that is extrapolated. As we know that QALY burden differs between (and within) PBCs and especially between the groups of PBCs with and without estimated outcome elasticities (see *Table 147* in *Appendix 3*),[ay] it is the values based on QALY burden in column (2) that are regarded as most credible and represent our central or best estimate.

A detailed breakdown of changes in expenditure and changes in QALYs across all PBCs is provided in *Table 150* in *Appendix 3,* both when the analysis is based on QALY ratios and when it is based on QALY burden of disease. A comparison of these values suggests that QALY effects for the other PBCs are generally lower and therefore the cost per QALY for each of these PBCs are, in general, higher when based on a proportionate effect on QALY burden. Of course, we have not directly observed QoL effects in these PBCs but inferred them from the proportionate effects that we can observe. Insofar as investment and disinvestment opportunities in these PBCs might have been more valuable (offered greater improvement in QoL)[az] than suggested by the implied PBC thresholds, then overall QALY effects will tend to be underestimated and the cost per QALY threshold overestimated. For the reasons discussed in previous sections, we regard all the costs per QALY threshold reported in column (2) of *Table 27* as on balance conservative with respect to overall health effects of a change in expenditure. However, the estimate of £10,187 may be conservative with respect to health effects (i.e. overestimated), as it is based on an extrapolation of the proportionate effects to measures of burden on these PBCs, rather than observations of the direct impact of changes in expenditure on QoL in these types of disease. This is especially important in PBC 5 (mental health disorders), which accounts for a large proportion of the change in overall expenditure (22%) and where a review of the evidence suggests that the investment and disinvestment opportunities in this PBC may have been more valuable than the implied PBC cost per QALY of £13,876 (see *Table 155*, *Appendix 3* and *Addendum 3: characterisation of the investment and disinvestment decisions in mental health – depression and schizophrenia*).[az] The lower cost per QALY threshold for the 11 PBCs with outcome elasticities (£5128) might be regarded as more secure in this respect but they only account for a proportion (38%) of any change in overall expenditure (see *Table 155* in *Appendix 3*).

Table 28 reports how the estimated QALY effects based on measures of QALY burden for each PBC can be decomposed into that part associated with life-year effects adjusted for quality and that part associated with 'pure' QoL effects. These results are similar to those reported in *Table 26* which were based on QALY ratios for the 11 PBCs with an estimated outcome elasticity. Those PBCs for which mortality is the major concern have a much greater share of total QALY effects associated with avoidance of premature death (e.g. PBC 2 and PBC 10) compared with those where QoL is the major concern (e.g. PBC 7). The differences tend to favour QALYs gained though avoidance of disability, which reflects the underestimation of the effects on 'pure' QoL when using QALY ratios based on estimates of YLL from GBD (see the discussion above).[aaa] The QALY to YLL ratios that are implied by this analysis are reported in *Appendix 3, Table 152*. As expected the implied QALY ratio across all 11 PBCs with outcome elasticities is higher (3.05[aab]) than reported in *Using ratios of quality-adjusted life-years to years of life* lost because the previous bias against QoL effects by using QALY ratios based on unadjusted GBD information has been removed.

In *Using ratios of quality-adjusted life-years to years of life lost* the ratios of QALYs to YLL due to disease in those PBCs where outcome elasticities could not be estimated could not be used to inform estimates of the threshold or indicate how any total health effects in these other PBCs are likely to be 'shared' between life-year effects adjusted for quality and that part associated with 'pure' QoL effects (see *Table 26*). By applying the observed proportionate effects of changes in expenditure to measures of QALY burden of disease in these other PBCs, the likely share of any effects on QALYs between avoidance of premature mortality and avoidance of disability more closely reflect the nature of these types of diseases (see *Table 28*). As expected, a much greater proportion of QALY effects are associated with QoL during the disease compared with the 11 PBCs where mortality-based outcome elasticities could be estimated. The share of effects in particular PBCs are also much more credible. For example, in PBC 5 (mental health disorders) the overwhelming share of QALY effects are associated with QoL itself and for others, such as PBC 12

TABLE 28 Decomposing estimated QALY effects by PBC

PBC		(1) QALY change (total)	(2) QALY change (death)	% QALY gained	
				(3) For premature death	(4) For disability while alive
2	Cancer	2121	1968	93	7
10	Circulatory	8347	5727	69	31
11	Respiratory	28,072	1072	4	96
13	Gastrointestinal	3922	1446	37	63
1	Infectious diseases	74	13	18	82
4	Endocrine	6905	380	5	95
7	Neurological	1361	60	4	96
17	Genitourinary	34	8	22	78
16	Trauma and injuries	0	0	N/A	N/A
18 + 19	Maternity and neonates	14	10	69	31
3	Disorders of blood	1215	62	5	95
5	Mental health	10,878	949	9	91
6	Learning disability	207	41	20	80
8	Problems of vision	561	22	4	96
9	Problems of hearing	1168	9	1	99
12	Dental problems	578	1	0	100
14	Skin	103	38	37	63
15	Musculoskeletal	1005	50	5	95
20	Poisoning and adverse events	42	7	16	84
21	Healthy individuals	40	6	16	84
22	Social care needs	0	0	N/A	N/A
23	Other	0	0	N/A	N/A

N/A, not applicable.

(dental problems), PBC 9 (problems of hearing) and PBC 8 (problems of vision); almost all effects are associated with QoL rather than mortality and life-years. For this, and the other reasons discussed above, the analysis based on measures of QALY burden are regarded as the best estimate of a cost per QALY ratio that reflects a more complete picture of the likely health effects of changes in overall expenditure.

Summary of the cost per quality-adjusted life-year threshold

The results of the three sequential steps of analysis described in this chapter are summarised in *Table 29*. In *From mortality to life-years* we explored ways in which the estimated effects on mortality from the econometrics work in *Chapter 3* might be better translated in to life-year effects by overcoming some of the limitations of mortality data available at PCT level and taking account of counterfactual deaths. The results of this analysis were reported in *Table 28* and are repeated in column (1) of *Table 29*.[aac] In *Adjusting life-years for quality-of-life* we considered how the estimated life-year effects might be adjusted for the QoL in which they are likely to be lived, taking account of the gender and the age at which life-years are gained or lost (see *Table 21*). The results of this analysis are repeated in column (2) of *Table 29*. Finally in *Including*

TABLE 29 Summary of cost per QALY threshold estimates

PBC grouping	(1) *From mortality to life-years* analysis	(2) *Adjusting life-years for quality-of-life* analysis	(3) *Including quality-of-life effects during disease* analysis
QoL associated with life extension	1	Norm	
QoL during disease	0	0	Based on burden
Best estimate			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	~4.1	~4.1	~4.1
QALYs per death averted	~4.1	~3.5	~14.9
(1) All big four programmes	£8080	£9631	£3036
(2) 11 PBCs (with mortality)	£15,628	£18,622	£5128
(3) All 23 PBCs	£17,663	£21,047	**£10,187**
Lower bound			
Effect of expenditure on mortality	Remainder of disease duration	Remainder of disease duration	Remainder of disease duration
YLL per death averted	~4.1	~4.1	~4.1
QALYs per death averted	~4.1	~3.5	~14.9
(4) All big four programmes	£3846	£4252	£674
(5) 11 PBCs (with mortality)	£6106	£6852	£860
(6) All 23 PBCs	£6901	£7744	**£1843**
Upper bound			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	2	2	2
QALYs per death averted	~2	~1.9	~7.2
(7) All big four programmes	£16,432	£17,456	£6292
(8) 11 PBCs (with mortality)	£32,387	£34,492	£10,626
(9) All 23 PBCs	£36,604	£38,983	**£21,111**

quality-of-life effects during disease we explored ways to also take account of the likely effects of changes in expenditure on QoL during disease as well as the effects associated with mortality and life-years [see *Table 29*, column (3)]. These estimates provide our central estimate of a cost per QALY threshold, because they make best use of available information while the assumptions required, which on balance are likely to be conservative with respect to health effects, appear more reasonable than the other alternatives available.[aad]

The estimate of £5128 per QALY [see *Table 29*, line (2)] is restricted to the effects of changes in expenditure in the 11 PBCs where outcome elasticities can be estimated. Although this might be regarded as more secure, these PBCs only account for a proportion of a change in overall expenditure [approximately 38%, see column (6) in *Table 108* in *Appendix 3*]. The threshold of £10,187 uses the estimated proportionate effects of expenditure on the QALY burden of disease in these PBCs as a surrogate for proportionate effects in the others (i.e. assuming that the effects that can be observed will be similar to those that cannot). As discussed in *Using estimates of the quality-adjusted life-years burden of disease* there are reasons to suspect that this may underestimate health effects in these PBCs which have most influence on the overall threshold. As in previous sections, no health effects are assigned to PBC 23 (GMS) on the basis that any health effects of this expenditure would be recorded in the other PBCs.[aae] Therefore, the best or central estimate of cost per QALY threshold is £10,187 [see *Table 29*, column (3), line (3)]. However, this estimate reflects changes in undiscounted QALYs associated with changes in expenditure. Although all the health effects of a change in expenditure are restricted to 1 year (so no discounting is necessary) some of the QALY effects of a change in mortality in that year will occur in future years, so in principle should be discounted. However, discounting these life-year effects, even at the higher rate of 3.5% recommended by NICE, only increases the cost per QALY threshold to £10,333 (see *Table 154* in *Appendix 3* for discounted values).

As in previous sections of this chapter, the upper and lower bounds for the cost per QALY thresholds in *Table 29*, column (3) are based on making the necessary assumptions about duration of health effects and how long a death might be averted optimistic (providing the lower bound for the threshold) or conservative (providing an upper bound for the threshold). The lower bound [see *Table 29*, lines (4)–(6)] is based on assuming that health effects are not restricted to 1 year but apply to the whole of the remaining disease duration of the population at risk in PBCs during 1 year. Although this combines optimistic assumptions, it is possible that at least some part of a change in expenditure may prevent disease so will have an impact on populations that are incident to PBCs in the future. Such effects are not captured in any of the estimates presented in this chapter so all are conservative with respect to this type of health effects of expenditure. The upper bound [see *Table 29*, lines (7)–(9)] is based on the combination of assuming that health effects are restricted to 1 year for the population currently at risk and that any death averted is only averted for 2 years (see *Summary of cost per life-year estimates*).

Chapter 5 Implications for a policy threshold

Introduction

The three sequential steps of analysis, which provide a cost per life-year threshold (see *Chapter 4, From mortality to life-years*) through a cost per life-year adjusted for quality (see *Chapter 4*, *Adjusting life-years for quality-of-life*) to a cost per QALY threshold (see *Chapter 4, Including quality-of-life effects during disease*), have been explained in *Chapter 4* using the analysis of 2006 expenditure and mortality data from 2006 to 2008 (see *Instrumental variable estimation* in *Chapter 3* and *Model estimation using 2006/7 expenditure data and mortality data for 2006/7/8: CARAN need and two market forces factors* in *Appendix 2*) to illustrate the implications for the threshold estimates. At each step we explored the different ways that routinely available data could be used and how additional information could improve our estimates. In doing so we identified a preferred analysis at each stage based on which made the best use of available information, whether or not the necessary assumptions appeared more reasonable than the alternatives available, and which provided a more complete picture of the likely health effects of a change in expenditure. Although other assumptions and judgements are possible that retain some level of plausibility, they do not necessarily favour a higher threshold. Indeed, when considered together, they suggest that on balance the central or best estimate presented in *Chapter 4* and in *Table 30* is, if anything, likely to be an overestimate (see *How uncertain are the estimates and what are the implications?* for a more detailed discussion and summary). In *Future research and improving estimates of the threshold* we discuss how some of these remaining uncertainties might be resolved through access to additional and better data and the type of analysis that would then be possible.

Re-estimating the cost per quality-adjusted life-year threshold using more recent data

The same methods of analysis can be applied to the econometric analysis of the 2008 expenditure and 2008 to 2010 mortality data (see *2008/9 expenditure data and mortality for 2008/9/10* in *Chapter 3* and *The correlation between the outcome and expenditure elasticities* in *Appendix 2*). The differences between the 2006 analysis reported in *Chapter 4* and the analysis of expenditure in 2008 reported below are the (i) total PBC expenditure; (ii) estimated expenditure elasticities; (iii) estimated outcome elasticities; (iv) observed PBC deaths by age and gender; and (v) LE by age and gender. The other information about QoL norms (see *Chapter 4*, *Quality of life based on the general population*), disease-related decrements in QoL (see *Chapter 4*, *Adjusting age-related quality-of-life for disease decrements*) and the information from GBD about incidence and duration of disease remain unchanged between 2006 and 2008 (we discuss how these estimates might be improved through access to more recent and better data in *Future research and improving estimates of the threshold*).

It should be noted that important improvements were made to the classification and collection of PBC expenditure data that took place after the 2006 data were collected. Therefore, the differences in threshold estimates between 2006 and 2008 partly reflect this (see *Comparing the cost of life-year estimates associated with different data sets* in *Chapter 3* and *Comparing the cost of life-year estimates associated with different data sets* in *Appendix 2*) so should not be overinterpreted. The results of the analysis of 2007 and 2008 expenditure are comparable in this respect, providing insights into how the threshold might change over time and with changes in the overall budget. The implications of this analysis on the need for periodic reassessment are discussed in *How does the threshold change with overall expenditure?* For the purposes of this methodological research the 2008 expenditure and 2008–10 mortality data were the latest to be analysed. As it is the analysis of the most recent data that is of most policy relevance, our discussion throughout this section is based on analysis of 2008 expenditure, although

TABLE 30 Summary of cost per QALY threshold estimates (expenditure in 2008)

PBC grouping	(1) *From mortality to life-years* analysis	(2) *Adjusting life-years for quality-of-life* analysis	(3) *Including quality-of-life effects during disease* analysis
QoL associated with life extension	1	Norm	
QoL during disease	0	0	Based on burden
Best estimate			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	~4.5	~4.5	~4.5
QALYs per death averted	~4.5	~3.8	~15.0
(1) All big four programmes	£10,220	£12,338	£4872
(2) 11 PBCs (with mortality)	£23,360	£28,045	£8308
(3) All 23 PBCs	£25,214	£30,270	**£12,936**
Lower bound			
Effect of expenditure on mortality	*Remainder of disease duration*	*Remainder of disease duration*	*Remainder of disease duration*
YLL per death averted	~4.5	~4.5	~4.5
QALYs per death averted	~4.5	~3.8	~15.0
(4) All big four programmes	£5083	£5811	£1194
(5) 11 PBCs (with mortality)	£8579	£9861	£1175
(6) All 23 PBCs	£9260	£10,644	**£2018**
Upper bound			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	2	2	2
QALYs per death averted	~2	~1.4	~6.6
(7) All big four programmes	£23,346	£26,138	£11,040
(8) 11 PBCs (with mortality)	£52,936	£59,151	£18,827
(9) All 23 PBCs	£57,136	£63,844	**£29,314**

the same sensitivity analysis (see *Which programme budget categories matter most?*) and analysis of uncertainty (see *How uncertain are the estimates and what are the implications?*) is available for 2006 and 2007 expenditure (see *How uncertain are the estimates?* in *Appendix 3*).

It is unnecessary to repeat all the analysis presented in *Chapter 4*, *From mortality to life-years*, *Adjusting life-years for quality-of-life* and *Including quality-of-life effects during disease* (the details of each stage of the analysis of 2008 data can be found in *Appendix 3*). Instead the results of the three sequential steps of analysis are summarised in *Table 30*. They include (i) the cost per life-year [see *Table 30*, column (1)],[a] based on the methods of analysis outlined in *Chapter 4, From mortality to life-years*; (ii) the cost per life-year adjusted for QoL [see *Table 30*, column (2)],[b] based on the methods of analysis outlined in *Chapter 4, Adjusting life-years for quality-of-life*; and (iii) the cost per QALY [see *Table 30*, column (3)], based on the methods of analysis outlined in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease*. These estimates, in *Table 30*, column (3), take account of the likely effects of changes in expenditure on QoL during disease as well as the effects associated with mortality and life-years; making best use of available information, while the assumptions required appear more reasonable than the other alternatives available. For this reason these estimates remain our central or best estimates for all the waves of expenditure and mortality data.

The estimate of £8308 per QALY [see *Table 30*, column (3), line (2)] is restricted to the effects of changes in expenditure in the 11 PBCs where outcome elasticities can be estimated. However, these PBCs only account for a proportion of the change in overall expenditure (approximately 50%, *Table 31*). As was explained in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* and *Summary of the cost per quality-adjusted life-year threshold*, the QALY threshold of £12,936 [see *Table 30*, column (3), line (3)] uses the estimated proportionate effects of expenditure on the QALY burden of disease in the 11 PBCs as a surrogate for proportionate effects in the others (i.e. assuming that the effects that can be observed will be similar to those that cannot), and represents our central or best estimate. As in previous sections, no health effects are assigned to PBC 23 or 22 (GMS and social care) on the basis that any health effects of this expenditure would be recorded in the other PBCs.[c] Although this estimate of £12,936 reflects changes in undiscounted QALYs associated with changes in expenditure, discounting the QALY effects only increases the cost per QALY threshold to £13,141.[d]

The upper and lower bounds for the cost per QALY thresholds in column (3) in *Table 30* are based on making the necessary assumptions about duration of health effects of expenditure and how long a death might be averted optimistic (providing the lower bound for the threshold) or conservative (providing an upper bound for the threshold). The lower bound [see *Table 30*, lines (4)–(6)] is based on assuming that the health effects of expenditure are not restricted to 1 year but apply to the whole of the remaining disease duration of the population at risk in PBCs during 1 year. Although this combines optimistic assumptions, it is possible that at least some part of a change in expenditure may prevent disease so will have an impact on populations that are incident to PBCs in the future. Such effects are not captured in any of the estimates presented in this report so all estimates are conservative in this respect (the possibility of a longer and more complex lag structure for the effects of expenditure are discussed in *Future research and improving estimates of the threshold*). The upper bound [see *Table 30*, lines (7)–(9)] is based on the combination of assuming that health effects are restricted to 1 year for the population currently at risk and that any death averted is only averted for 2 years (see *Chapter 4, Summary of cost per life-year estimates*).

The estimated QALY effects associated with each PBC can be decomposed into that part due to life-year effects adjusted for quality and that part associated with effects on QoL during disease. The proportionate share of these different aspects of the total health effects are the same as reported in *Table 28*; where those PBCs for which mortality is the major concern have a much greater share of total QALY effects associated with avoidance of premature death (e.g. PBC 2 and PBC 10) than those where QoL is the major concern (e.g. PBC 7).

TABLE 31 Impact of each PBC on the overall cost per QALY threshold (2008)

PBC		(1) % Share of change in overall expenditure	(2) % Share of total health effects (QALY)	(3) Elasticity of the threshold[a]	(4) PBC cost per QALY (£)
2	Cancer	4.47	3.41	0.34	16,997
10	Circulatory	7.59	13.95	1.40	7038
11	Respiratory	4.58	29.67	2.97	1998
13	Gastrointestinal	3.20	5.68	0.57	7293
1	Infectious diseases	3.27	2.03	0.20	20,829
4	Endocrine	1.89	7.84	0.78	3124
7	Neurological	5.98	14.11	1.41	5480
17	Genitourinary	4.64	1.37	0.14	43,813
16	Trauma and injuries	7.70	0	0	N/A
18 + 19	Maternity and neonates	6.83	0.03	< 0.01	2,969,208
3	Disorders of blood	2.06	2.82	0.28	9419
5	Mental health	17.86	12.32	1.23	18,744
6	Learning disability	1.04	0.09	0.01	149,883
8	Problems of vision	1.94	0.55	0.05	45,788
9	Problems of hearing	0.87	1.81	0.18	6239
12	Dental problems	2.89	0.88	0.09	42,472
14	Skin	1.97	0.25	0.03	101,042
15	Musculoskeletal	3.63	3.00	0.30	15,628
20	Poisoning and adverse events	0.93	0.11	0.01	113,546
21	Healthy individuals	3.53	0.09	0.01	526,771
22	Social care needs	3.00	0	0	N/A
23	Other	10.14	0	0	N/A

N/A, not applicable.

a The proportionate change in the overall cost per QALY threshold due to a 10% increase or decrease in the health effects associated with the PBC. These elasticities are correct up to a 50% change in health effects.

Which programme budget categories matter most?

Which PBCs have the greatest influence on the overall threshold depends, to a large extent, on how a change in overall expenditure is allocated to the different PBCs [see column (1) in *Table 31*],[e] i.e. those that account for a greater share of the change in expenditure will tend to have the greater influence. However, it also depends on the proportionate effect of a change in PBC expenditure on the QALY burden associated with the PBC[f] and the scale of the QALY burden (for the population at risk) associated with the type of diseases that make up each PBC.[g] These determine the cost per QALY associated with each PBC

[see *Table 31*, column (4) and *Table 180* in *Appendix 3*]. The share, attributable to each PBC, of the total health effects of a change in overall expenditure [see column (2) of *Table 31*] is the combined effect of all of these. The proportionate impact on the overall cost per QALY threshold of a 10% change in PBC health effects in *Table 31*, column (3) gives an indication of how sensitive the overall threshold is to the estimate of health effects associated with each PBC. It starts to suggest where further efforts to improve estimates of the overall threshold might be most usefully directed.

Although the 11 PBCs where outcome elasticities could be estimated only account for 50% of the change in overall expenditure, they account for 78% of the overall health effects. Within this group some PBCs contribute more than others. For example, PBC 11 (respiratory) accounts for a greater share of total health effects and has a higher elasticity (2.97%) than PBC 10 (circulatory) even though the latter accounts for a greater part of a change in overall expenditure. The reason is that the cost per QALY associated with changes in expenditure in PBC 11 is lower than PBC 10 and much lower than the overall threshold (so generates more health effects for the same, or even smaller, change in expenditure).[h] The elasticities in *Table 31*, column (3), are instructive, for example the elasticity for PBC 11 suggests that even if the health effects of a change in expenditure in this PBC were overestimated by 30% the overall threshold would increase by 8.90% to £14,089. All other PBCs have much less influence in this respect. Nonetheless, PBC 10 is important compared with others as it does contribute a large share of total health effects and has one of the highest elasticities (1.40%).[i] Also PBC 7 (neurological), although accounting for a smaller share of a change in overall expenditure, does contribute a large share of total health effects with an elasticity of 1.41% and a relatively low cost per QALY associated with changes in PBC expenditure.[j]

The other 11 PBCs, where outcome elasticities could not be estimated (excluding PBC 23, GMS) account for a large part of a change in overall expenditure (40%) but only 22% of the overall health effects (i.e. the cost per QALYs associated with a change in expenditure in these PBCs is, in general, higher). Of course, we have not directly observed QoL effects in these PBCs but inferred them from the proportionate effects that we can observe. Insofar as investment and disinvestment opportunities in these PBCs might have been more valuable (i.e. offered greater improvement in QoL) than suggested by the implied PBC thresholds in *Table 31*, column (4), the overall QALY effects will tend to be underestimated and the overall cost per QALY threshold will be overestimated.

Programme budget category 5 (mental health disorders) accounts for a large proportion of the change in overall expenditure (18%), contributes most to the overall health effects (12%) and has the highest elasticity (1.23%) compared with these other PBCs. The cost per QALY associated with this PBC (£18,744) is based on an extrapolation of estimated proportionate effects to a population-based measure of QALY burden in this PBC, rather than observations of the direct impact of changes in expenditure on QoL in the types of diseases that make up the PBC. Evidence that is available suggests that the investment and disinvestment opportunities in this PBC may have been more valuable than this implied cost per QALY. A review of the evidence of the cost-effectiveness of the investment and disinvestment opportunities that have been available in mental health during this period is reported in *Appendix 3, Addendum 3: characterisation of the investment and disinvestment decisions in mental health – depression and schizophrenia*. A search for evidence about interventions in those ICD-10 codes that contribute most to the PBC (based on prevalence or the contribution to the variance in PBC costs), suggests that pharmacological, psychological and social interventions for depression are all more cost-effective (in general much < £10,000 per QALY) than the overall threshold, and significantly more valuable than the implied QALY threshold for this PBC. Based on the contribution that each ICD-10 code makes to variance in HES costs across PCTs, it is schizophrenia that contributes most.[k] Although interventions that may have been invested or disinvested in in schizophrenia are, in general, less cost-effective (in general < £24,000 per QALY) than those available for depression, they do not appear any less valuable than the implied cost per QALY of this PBC in *Table 31*.[l]

It is very important not to misinterpret the cost per QALY associated with each PBC in column (4) of *Table 31*. These are not cost-effectiveness thresholds. That is, they do not represent the QALYs likely to be

forgone due to costs imposed (e.g. by the approval of a new and more costly technology by NICE) in a particular PBC because NHS expenditure is not devolved and constrained to PBC specific budgets. Rather, the overall expenditure is constrained through government decisions about public expenditure, but within the NHS resources (at the margin at least) can be reallocated in anything other than the very short run across different activities and disease areas. For example, the additional net NHS costs of approving a new but more costly technology in PBC 10 (circulatory) will not be restricted to the circulatory PBC [7.6% will, see column (1) in *Table 31*], but are likely to be reallocated in the same way as an equivalent reduction in overall expenditure [i.e. the shares of a change in overall expenditure in *Table 31*, column (1)].[m] Therefore, the relevant cost per QALY threshold for a technology in the circulatory PBC is not £7038 but the overall threshold of £12,936.

The primary purpose of *Table 31* is to identify which PBCs have greatest influence on the estimate of the overall threshold and examine whether the implied values for the other PBCs are likely to lead to under- or overestimation. There are differences in the implied cost per QALY ratio between PBCs, including some with very high implied cost per QALY (e.g. PBCs 18 + 19, 20 and 21 reflecting small estimated health effects in the denominator), although they have limited influence on the overall estimate of the threshold. These differences in the implied cost per QALY across PBCs should not be overinterpreted. For example, these differences could be interpreted as evidence of a misallocation of resources (e.g. reallocating expenditure from PBCs with higher to lower cost per QALY would improve health) if the purpose of the NHS and PCTs is to maximise unweighted QALYs. However, rather than a misallocation, these differences (between the first 11 PBCs) might indicate that the actual QoL effects of expenditure are proportionally greater (lower) than mortality effects in those with a higher (lower) cost per QALY, or that the health effects in these PBCs are more socially valuable with a greater implicit weight attached to QALYs gained or lost in these areas (e.g. maternity and neonates). The higher cost per QALY for the remaining PBCs may reflect that the actual QoL effects of changes in expenditure may be more than proportional to QALY burden (e.g. evidence from mental health PBC suggests that investment and disinvestment opportunities may have been more valuable than the implied PBC cost per QALY of £18,744). Additionally, it was not possible to estimate the health effects of changes in PBC expenditure simultaneously across PBCs. Consequently, the effects of changes in expenditure in one PBC may be recorded in ICD-10 codes relevant to other PBCs, so it is possible that PBCs with a higher implied cost per QALY may be contributing health effects to other (recipient) PBCs.[n]

Whether or not these differences are regarded as evidence of a misallocation, however, is unimportant for an estimate of a cost per QALY threshold that reflects the health effects of how changes in overall expenditure are currently expected to be allocated. Whether or not PCTs do or should maximise QALYs has no influence on the current estimate of the threshold, given that NICE currently uses an unweighted QALY threshold.[o] In addition, insofar as local objectives do change or national policy does reallocate expenditure, the impact of these and other changes that will take place over time will be reflected in estimates of the threshold in subsequent periods once these changes have taken place (see *How does the threshold change with overall expenditure?*).

How uncertain are the estimates and what are the implications?

There are a number of sources of uncertainty which contribute to an assessment of how uncertain a central or best estimate of the cost per QALY threshold might be. There are three reasons why uncertainty in the estimate of the threshold might be of policy interest: (i) the uncertainty in the parameters that determine the threshold might influence the mean or expected value of the threshold if they have a non-linear relationship to the threshold or when they have a multilinear relationship but are correlated with each other; (ii) the consequences of over- or underestimating the threshold differ so the uncertainty may have an influence on the extent to which a policy threshold (a single value that can be compared to the ICER of a new technology) should differ from the mean or expected value of the central or best estimate; and (iii) in conjunction with other methods of analysis[p,95] it can indicate the potential value of gathering more information to improve these estimates in the future. Of course, hypothesis testing and the

traditional rules of inference associated with it, such as statistical significance, *p*-values and confidence intervals, have no relevance when making unavoidable decisions about policy relevant quantities based on information currently available and the best use thereof.[96]

An assessment of parameter uncertainty

Two sets of parameters are critical to the threshold, the expenditure elasticities estimated for each of the 23 PBCs, and the outcome elasticities estimated for 11 of these. These parameters are estimated with uncertainty, indicated by the standard errors on the relevant coefficients in the econometric analysis outlined in *Chapter 3* and detailed in *Appendix 2*. As these statistical models estimate coefficients using normality on the relevant scale, normal distributions can be assigned to each of these estimated coefficients, each with a mean and standard deviation based on the results of the econometric analysis.[q] These distributions, represent the uncertainty in the mean estimate of each of the parameters and can be propagated through the various calculations required to estimate an overall cost per QALY threshold (i.e. through the sequence of analysis detailed in *Chapter 4, From mortality to life-years, Adjusting life-years for quality-of-life* and *Including quality-of-life effects during disease*) using Monte Carlo simulation which randomly samples from the assigned distributions. The results of each random sample represent one possible realisation of the overall threshold, given the uncertainty in estimates of the mean parameter values that determine it. By repeatedly sampling, a distribution of potential values that the overall threshold might take can be revealed. The results of this simulation are illustrated in *Figure 5* which shows the cumulative probability density function for a cost per QALY threshold based only on the 11 PBCs with estimated outcome elasticities and for all 23 PBCs. It represents the probability (on the *y*-axis) that the threshold lies below a particular value.

It has already been noted that restricting attention only to changes in expenditure in those 11 PBCs where an outcome elasticity can be estimated results in a much lower estimate of the threshold than considering all changes in expenditure across all PBCs This lower estimate of £8308 per QALY is much less uncertain but these PBCs only account for 50% of a change in overall expenditure, so it is the higher estimate, for all 23 PBCs, that is of most relevance for policy (see *Re-estimating the cost per quality-adjusted life-year threshold using more recent data* and *Chapter 4, Summary of the cost per quality-adjusted life-year threshold*). The fact that this estimate is more uncertain simply reflects the quality and quantity of data currently available. As useful analysis should endeavour to faithfully characterise uncertainty in policy relevant quantities, rather than select those

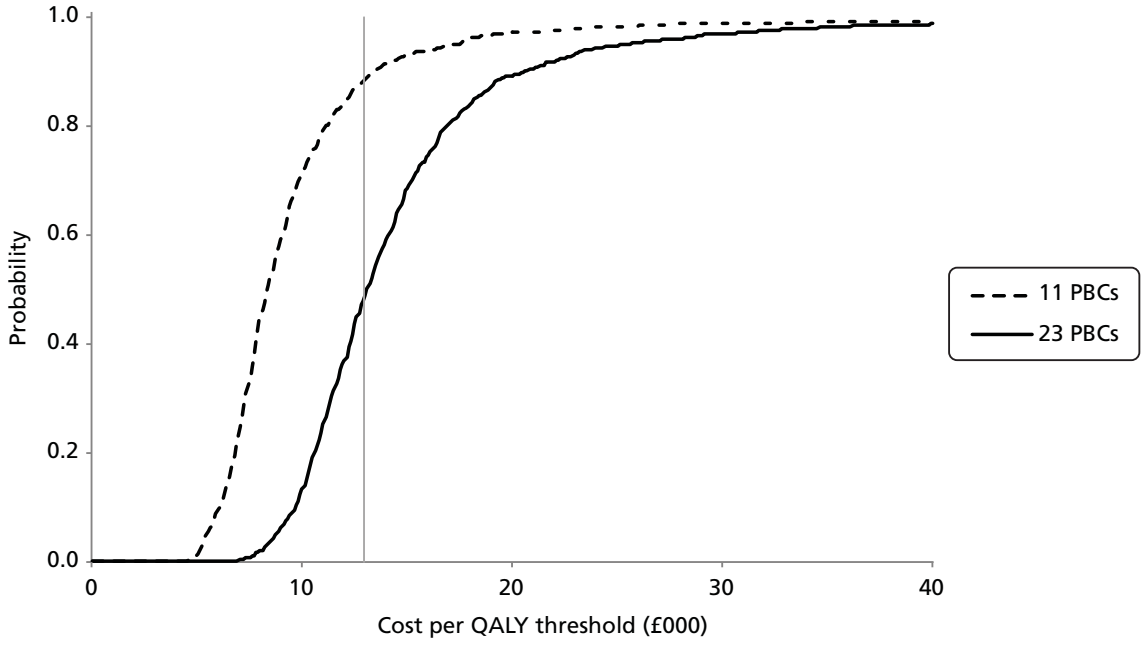

FIGURE 5 Cumulative probability density function for the cost per QALY threshold.

quantities or questions for which precise estimates are possible, it is the more uncertain estimate for all 23 PBCs that should be of primary interest. The values that are used to generate *Figure 5* are available in *Table 183* in *Appendix 3*. They indicate that the probability that the overall threshold is < £20,000 per QALY is 0.89 and the probability that it is < £30,000 is 0.97.

The implications of uncertainty

Integrating this parameter uncertainty into the estimates of the overall threshold does not change the mean or expected value of the cost per QALY threshold.[r] This is to be expected as the expenditure and outcome elasticities have a multilinear relationship to the overall threshold and the analysis sampled independently from the distributions assigned to estimated coefficients. We did investigate the potential correlation between the expenditure and outcome elasticities by repeatedly re-estimating both based on randomly sampling with replacement the 152 PCTs – creating bootstrapped data sets where the original PCTs could appear more than once or not at all in the re-sampled data. This analysis indicated a small positive correlation between outcome and expenditure elasticities in four PBCs using 2006 expenditure data (see *Analysis of programme budgeting expenditure for 2007/8 and mortality data for 2007/8/9* in *Appendix 2*). Such levels of correlation will tend to have a modest but positive influence on the mean value of the cost per QALY threshold.[s]

Uncertainty in the estimate of the overall threshold means that a policy threshold set at its mean or expected value may be inappropriate. Insofar as the consequences (to the NHS) of under- or overestimation are symmetrical, then the expected or mean value would be the appropriate policy threshold irrespective of the scale of uncertainty. However, the consequences of overestimating the threshold are more serious than underestimating it. This is illustrated in *Figure 6* which is similar to *Figure 1* presented in *Chapter 2*.

Figure 6 shows the impact on NHB if the central estimate of £20,000 is in fact an overestimate and the threshold should be £10,000 per QALY. In these circumstances the technology should not have been approved at price P2. This overestimation leads to a loss of NHB of 2 QALYs as a consequence. Alternatively, the central estimate of £20,000 may be an underestimate and the threshold should be £30,000 per QALY. In these circumstances the technology could just as easily have been rejected or approved based on the central estimate and price P2. However, if the threshold is £30,000 per QALY rather than £20,000 it should be approved. If it was rejected, this underestimation leads to a loss of

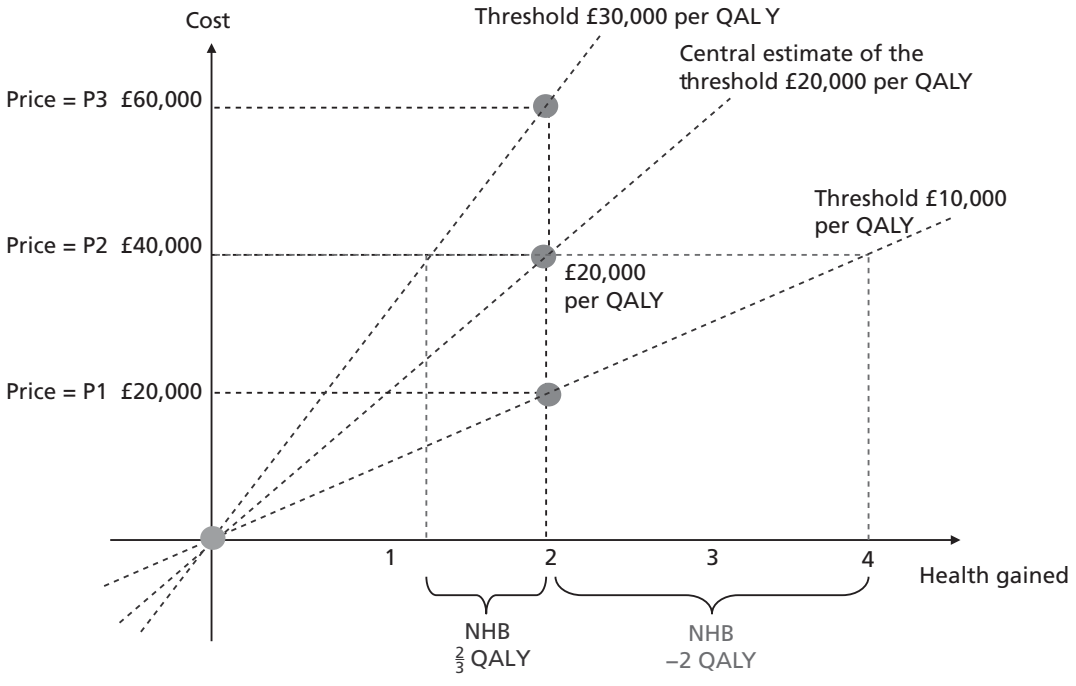

FIGURE 6 Consequences of over- and underestimating the overall threshold.

NHB of two-thirds of a QALY as a consequence (i.e. less than the loss associated with the same scale of overestimation). If the scale of under- or overestimation of the central estimate is equally likely (the distribution of possible values of the threshold is symmetrical) then using the mean or expected value as a policy threshold (one that can be compared with the ICER of a new technology) will lead to a loss of net benefit.[t] A policy threshold that represents the maximum the NHS can afford to pay for QALY gains offered by a technology will be lower than the mean of the cost per QALY threshold (i.e. < £12,936) to compensate for the more serious consequences of overestimating the 'true' value.[u] Importantly, this remains the case even if effects are expressed in terms of their equivalent consumption value (net monetary benefit based on WTP) rather than a measure of NHB.[v]

How much lower a policy threshold should be set below the mean or expected value depends on three considerations: (i) the scale of uncertainty in the estimate of the threshold (greater uncertainty implies a lower policy threshold); (ii) the scale of the incremental costs relative to incremental health benefits offered by the technology (policy threshold should only be equal to mean estimate if there are no additional NHS costs associated with the technology); and (iii) the skewness of the distribution of cost per QALY threshold (a negative skew tends to offset these effects – see *Figure 52* in *Appendix 3*). The overall scale of the impact on a policy threshold will be specific to the additional NHS costs associated with a technology as well as the other sources of uncertainty, discussed below, and possible correlations between expenditure and outcome elasticities, discussed above. We have not quantitatively integrated all these considerations into an analysis of an appropriate policy threshold, although this may be possible in future research.

Structural uncertainty

The uncertainty associated with the parameters estimated in the econometric models is only one, and not necessarily the most important, source of uncertainty associated with the cost per QALY threshold. The parameter uncertainty presented above is conditional on the econometric model being 'correct'. In particular, that the instruments used to identify the causal effect on health of changes in expenditure are valid. Although all the models passed the relevant tests of validity, there remains some uncertainty about the validity of the instruments used, i.e. there remains structural or model uncertainty (see *Chapter 3* for an overview).[97] For this reason we undertook an analysis of how sensitive estimates of outcome elasticities might be to instrumental validity (see *The identification of values to be imposed on the coefficients on the excluded instruments* in *Appendix 2*). We were also able to specify a distribution for the measure of instrumental validity used in this sensitivity analysis, i.e. how 'likely' each value might be (see *Obtaining the outcome elasticities associated with sampled coefficients on the excluded instruments* in *Appendix 2*). Therefore, there are two 'levels' of uncertainty: (i) the parameter uncertainty (uncertainty in estimated coefficients given a particular 'level' of instrumental validity); and (ii) the structural uncertainty in the level of instrumental validity. Both sources of uncertainty were integrated by randomly sampling the distribution of measures of instrumental validity and then, conditional on this sampled value, re-estimating outcome equations and sampling the estimated coefficients. This analysis in *Obtaining the outcome elasticities associated with sampled coefficients on the excluded instruments* of *Appendix 2* shows that model or structural uncertainty constitutes a greater part of the overall uncertainty associated with the outcome elasticities, so fully integrating this source of uncertainty is likely to have a significant impact on the extent to which a policy threshold should be lower than the mean or expected value of the cost per QALY threshold. Importantly, this additional structural uncertainty has little effect on the point estimates of the outcome elasticities, i.e. the central estimate of the cost per QALY threshold is robust to uncertainty in instrumental validity in the econometric models.[w]

Other sources of uncertainty

Of course the parameter and structural uncertainty associated with the econometrics work outlined in *Chapter 3* is itself only one source of uncertainty associated with the estimated cost per QALY threshold. Each of the steps of analysis in *Chapter 4, From mortality to life-years, Adjusting life-years for quality-of-life* and *Including quality-of-life effects during disease* explored the different ways routinely available data could be used and how additional information could improve the estimates. We identified a preferred analysis (or scenario) at each stage based on which made the best use of available information, whether or not the

assumptions required appeared more reasonable than the other alternatives available, and which provided a more complete picture of the likely health effects of a change in expenditure. Insofar as the preferred analysis is the only plausible scenario, there would be no other sources of uncertainty. However, other assumptions and judgements are possible, which although they may be judged less credible might, nonetheless, have some probability of being the most credible (given the evidence currently available). Therefore, there will be uncertainty between these alternative 'scenarios' as well as within each (the parameter and model uncertainty described above).[95] Although in principle this can be integrated into the analysis even in the absence of data to test alternative views,[98] we do not do so here as assigning probabilities to alternative scenarios would be somewhat speculative and inevitably disputed. Instead we offer a summary of the qualitative considerations. Of course any increase in the uncertainty associated with the central estimate of the cost per QALY will impact on the extent to which a policy threshold should be lower than the mean. However, a critical issue is whether or not consideration of other 'scenarios' might change this central estimate (e.g. if scenarios that lead to a lower estimate are judged more credible than those that lead to higher ones). In other words the question is whether on balance the central or best estimate of £12,936 in *Table 30* is likely to be an under- or overestimate of the cost per QALY threshold.

Most of the considerations have been discussed in detail throughout *Chapter 4* so are only briefly summarised here. The key assumptions made in *Chapter 4* that underpin the central estimate of the cost per QALY threshold reported in *Table 30* are briefly summarised in *Table 32*, including a brief indication why such an assumption was required, the likely qualitative effect that each is likely to have on estimates for the health effects of changes in expenditure and where these are introduced in *Chapter 4*.

On the one hand, there are some reasons why the health effects might be overestimated and the central estimate of the QALY threshold underestimated (e.g. see assumptions 1–4 in *Table 32*). Calculating the life-years lost that account for deaths that would have otherwise occurred as described in *Chapter 4*, *Years of life lost and accounting for counterfactual deaths* and *Inferring excess deaths* is equivalent to assuming that those deaths averted by a change in expenditure returns the individuals to the mortality risk of the general population (matched for age and gender). Although this appears more credible than the alternative assumptions that could be made (e.g. restricting life-year effects of changes in mortality to the period of observed variation in mortality outcomes), it is likely to be optimistic with respect to the life-year effects of changes in mortality, tending to underestimate the cost per QALY threshold.

On the other hand there are a number of reasons why the central estimate might be overestimated (e.g. see assumptions 5 and 6 in *Table 32*). The health effects of a change in expenditure are restricted to the population at risk during 1 year. This is undoubtedly pessimistic in three respects: (i) it means that effects on QoL during disease only occur for 1 year (the effect of investment that might have long-term effects on QoL, e.g. hip replacement are excluded); (ii) mortality effects are also restricted to 1 year, so the full effect of investments that reduce mortality for patients throughout their disease duration, not just in the first year, will not be captured; and (iii) changes in expenditure that reduce incidence in the at risk population in the future (i.e. prevention of disease) will not be captured either. A more formal and longer lag structure in the estimation of outcome elasticities would be likely to capture more health effects of a change in expenditure.

The effect of other assumptions that have been necessary are more ambiguous although some evidence suggests their net effect may be conservative with respect to health effects of changes in expenditure (e.g. see assumptions 7–9 in *Table 32*). The observed effects of a change in expenditure on mortality and life-years in the 11 PBCs where outcome elasticities could be estimated was used as a surrogate for health effects in the other 12 PBCs (excluding GMS), i.e. the estimated effects of a change in expenditure that could be observed were used to inform those effects that currently, at least, cannot. This approach is not necessarily optimistic with respect to overall health effects. In fact, there are reasons to believe it may underestimate them (overestimate the threshold). As discussed previously in *Chapter 4, Summary of the cost per quality-adjusted life-year threshold* and *Re-estimating the cost per quality-adjusted life-year threshold using more recent data*, if this means of extrapolating from observed to unobserved effects is rejected then threshold estimates could be based only on the health effects of changes in expenditure in

TABLE 32 Summary of assumptions and their likely impact on the central estimate of £12,936 per QALY

Assumption	Justification	Likely impact on estimates	Reference
1. Deaths averted by a change in expenditure returns an individual to the mortality risk of the general population (matched for age and gender)	No data to directly estimate the effects on survival. Appears more credible than restricting life-year effects of changes in mortality to the period of observed variation in mortality outcomes	Overestimate health effects	*Chapter 4, Introduction* and *Summary of cost per life-year estimates* *Chapter 4*, notes b and w, and *Chapter 5*, note ak
2. Expenditure and outcome elasticities are uncorrelated	Expenditure and outcome equations were estimated separately	If the small but positive correlation between outcome and expenditure elasticises found in four PBCs was applied to all PBCs it is likely to have a modest but positive impact on the expected value of the threshold	*How does the threshold change with overall expenditure?* *Chapter 5*, note u
3. Mortality effects of changes in expenditure (reported at PCT level) can be applied to all mortality recorded in a PBC	Assuming no health effects of expenditure in areas of disease where mortality is not recorded at PCT level or in over 75-years age groups appears arbitrary and less plausible than basing estimates of effects that cannot be observed on what can	Although including persons aged over 75 years mortality may overestimate the effects on observed PBC deaths (if mortality in older ages groups is less sensitive to changes in expenditure) it has a much more limited impact on life-year effects (i.e. including mortality above LE reduces net YLL)	*Chapter 4, Mortality and years of life lost coverage*, *Life expectancy and years of life lost*, *Years of life lost and accounting for counterfactual deaths* and *Inferring excess deaths* *Chapter 4*, notes b, q and s
4. The PBC QALY effects are a weighted average of effects within each of the ICD-10 codes that contribute to the PBC based on the proportion of the total PBC population within each contributing ICD-10 code	PBC costs are not available at ICD-10 level across PCTs. Although costs from HES data are available at ICD-10 level they are only a small component of total PBC costs and contribute very little to the variability in PBC costs across PCTs, especially when considering PBCs where mortality effects could not be estimated	There is no information about how changes in PBC expenditure are allocated to particular ICD-10 codes so the effect is unclear. However, it may overestimate health effects if investment within a PBC is focused on ICD-10 codes where expenditure has greater health effects and disinvestment focuses on ICD-10 codes with less health effects	*Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* and *Using estimates of the quality-adjusted life-year burden of disease* *Chapter 4*, notes an and au, and *Chapter 5*, note ai
5. Health effects of changes in expenditure are restricted to the population at risk during 1 year	It was not possible to estimate a longer and more complex lag structure. Assuming that estimated health effects could be applied to the whole remaining duration of disease for the population at risk appears less plausible	Underestimate health effects	*Chapter 4, Introduction, Summary of cost per life-year estimates, Summary of the cost per quality-adjusted life-year threshold* and *Future research and improving estimates of the threshold* *Chapter 4*, note a, and *Chapter 5*, notes aj and ao

continued

TABLE 32 Summary of assumptions and their likely impact on the central estimate of £12,936 per QALY (*continued*)

Assumption	Justification	Likely impact on estimates	Reference
6. Health effects restricted to the PBC in which expenditure changes. No health effects associated with changes in GMS expenditure (or PBC 22, social care)	It was not possible to estimate outcome equations for PBCs simultaneously so estimated outcome elasticities do not account for health effects due to changes in expenditure in other PBCs	Likely to underestimate health effects because effects of changes in expenditure in 'contributory' PBCs will not be reflected in estimates of health effects in other (recipient) PBCs unless they happen to be correlated with changes in expenditure in these PBCs	*Chapter 4, Years of life lost and accounting for counterfactual deaths* and *Summary of cost per life-year estimates*, *Which programme budget categories matter most?* and *Future research and improving estimates of the threshold* *Chapter 4*, notes c, m and u, *Chapter 5*, notes b, e, p, an and ar
7. Same proportional effect on QALY burden of disease as the estimated proportional effect on the life-year burden of disease	Estimates of effects on mortality and life-years are used as a surrogate for effects on QoL. Appears more plausible than assuming no effects of NHS expenditure on QoL outcomes	May underestimate the QoL effects of changes in expenditure in these PBCs if effects are more than proportional to mortality and life-year effects or overestimate them if they are less than proportional	*Chapter 4, Summary of the cost per quality-adjusted life-year threshold based only on mortality effects* and *Using estimates of the quality-adjusted life-year burden of disease* *Chapter 4*, note ad
8. Life-year effects are lived at a QoL that reflects a proportionate improvement to the QoL with disease	Consistent with using estimated mortality and life-year effects as a surrogate for a more complete measure of health outcome (QALYs). Appears more plausible than assigning QoL norms or a QoL with disease to life-year effects	This assumption is more conservative than assigning QoL norms to life-years (assuming that all disease is acute), but less conservative than assigning QoL with disease (assuming that all life-years would be lived in the diseased state until death)	*Chapter 4, Summary of the cost per quality-adjusted life-year threshold based only on mortality effects* and *Using estimates of the quality-adjusted life-year burden of disease* *Chapter 4*, notes ad and ap
9. Proportional effect on QALY burden of disease in PBCs where mortality effects could not be estimated is assumed to be the same as the overall proportional effect on the life-year burden of disease across those PBCs where mortality effects could be estimated	Consistent with using estimated mortality and life-year effects as a surrogate for health effects (QALYs) where mortality effects cannot be directly estimated. Appears more plausible than assuming no health effects of NHS expenditure in these PBCs	May underestimate the QALY effects of changes in expenditure in these PBCs if effects are more than proportional to QALY burden of disease. Other evidence suggests that the effect of this assumption may be to underestimate health effects in key PBCs (mental health)	*Chapter 4, Using estimates of the quality-adjusted life-year burden of disease, Summary of the cost per quality-adjusted life-year threshold* and *Which programme budget categories matter most?* *Chapter 4*, notes aw and ax, *Chapter 5*, notes g, al, am

those PBCs where outcome elasticities can be estimated. This generates a much lower cost per QALY threshold (£8308) even if that portion of GMS expenditure was allocated to these 11 PBCs (see *Chapter 4, Summary of cost per life-year estimates*). Alternatively, taking account of the large proportion of the change in expenditure allocated to the other 11 PBCs but assuming that there are no health effects of expenditure in all these other PBCs is not plausible. The evidence that is available about the value of investment and disinvestment opportunities in the most important of these other PBCs (PBC 5 mental health disorders), suggests that the health effects of changes in expenditure in this PBC might be underestimated and the central estimate of the threshold overestimated (see *Which programme budget categories matter most?* and *Addendum 3: characterisation of the investment and disinvestment decisions in mental health – depression and schizophrenia* in *Appendix 3*).

In addition, we have also shown that the uncertainty associated with our central estimate (from all sources) means that an appropriate policy threshold is likely to be below its mean or expected value. Finally, in *Impact of investment, disinvestment and non-marginal effects* we explore how the threshold is likely to differ when considering opportunities to make investments (i.e. an increase in overall expenditure, or cost saving accruing to the NHS), and when disinvestment is required (a reduction in overall expenditure or costs imposed on the NHS). This analysis shows that a cost per QALY threshold relevant to technologies which impose costs on the NHS is likely to be less than our central estimate of £12,936. Therefore, although other assumptions and judgements are possible that retain some level of plausibility, they do not all favour a higher threshold. Indeed, when considered together, they suggest that on balance the central or best estimate of £12,936 presented in *Table 30* is, if anything, likely to be an overestimate. In *Future research and improving estimates of the threshold* we discuss how some of these remaining uncertainties might be resolved through access to additional and better data and the type of analysis that would then be possible.

Impact of investment, disinvestment and non-marginal effects

The central estimate of the cost per QALY threshold in *Table 30* is based on estimates of the health effects of changes in expenditure across all 152 PCTs, some of which will be making investments (where expenditure is increasing) and others making disinvestments (where expenditure is reduced or growing more slowly). The cost per QALY threshold, however, is likely to differ across these different types of PCTs. This is illustrated in *Figure 7* where the total observed variation in expenditure includes the

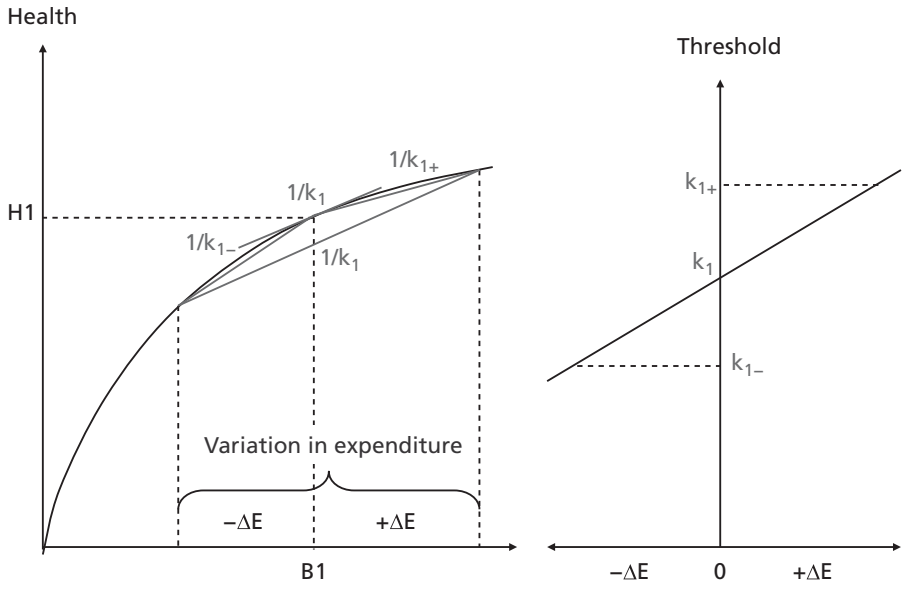

FIGURE 7 Investment, disinvestment and budget impact. –ΔE, disinvestment; +ΔE, investment; B1, current budget; H1, current level of health; k_1, cost per QALY threshold; k_{1-}, QALY threshold associated with disinvestment; k_{1+}, QALY threshold associated with investment.

impact of disinvestment (–ΔE) (e.g. where costs are imposed on the NHS by the approval of a more costly technology) and investment (ΔE) (e.g. where cost savings are accruing to the NHS). The central estimate of the cost per QALY threshold is the health effect of a change in expenditure across this variation in expenditure (k_1).[x] One would expect that, other things being equal, more expenditure (expanding the budget from B1) would increase health but at a diminishing rate. Therefore, the amount of health displaced by disinvestment, or a reduction in expenditure, would be expected to be greater, i.e. the threshold associated with –ΔE (k_1–) will be lower than the central estimate, k_1. Equally, the health gained from investments, or an increase in expenditure, would be expected to be lower, that is the threshold associated with +ΔE (k_1+) will be higher than k_1.

We have been able to examine this by re-estimating the outcome and expenditure elasticities separately for those PCTs where their actual budget is under the target allocation from the Department of Health resource allocation formula (i.e. those under greater financial pressure and more likely to be disinvesting than investing), and those that are over target (under less financial pressure and more likely to be investing than disinvesting). The detail of this analysis (based on 2006 expenditure and restricted to the 'big four' PBCs) are reported in *Comparing outcome models for 'high' spending and 'low' spending primary care trusts* in *Appendix 2*. The results confirm what would be expected given *Figure 7* and the discussion above – the outcome elasticities are smaller (in absolute terms) for all four PBCs in the group of PCTs above their target allocation and larger for all four PBCs below their target allocation. Therefore, the health effects of changes in expenditure are greater in all these PBCs when PCTs are under more financial pressure and are more likely to be disinvesting then investing. The cost per life-year estimates for these PBCs are reported in *Appendix 2*: £10,604 for all PCTs combined (k_1); £8441 for those PCTs under their target allocation (i.e. k_1– associated with –ΔE); and £14,083 for PCTs over their target allocation (i.e. k_1+ associated with +ΔE). Although these cost per life-year estimates are not based on the same calculations as *Chapter 4, From mortality to life-years*, they do start to indicate the scale of the effect on a threshold that is most relevant for new technologies that impose net costs on the NHS.

Expenditure elasticities for these PBCs also differ between these groups of PCTs – they are higher for those under their target allocation. These PBCs together consistently offer the greatest value in terms of cost per death averted, life-year or QALY (see *Tables 30* and *31*). This suggests that budget impact not only displaces more valuable activities within each PBC (outcome elasticities are larger), but that overall expenditure tends to be reallocated to more valuable PBCs. The effect of this reallocation on the overall threshold is not captured in the cost per life-year estimates reported above, which are restricted to these four PBCs. Therefore, extending this type of analysis to all PBCs in future research is likely to show that the effect on the cost per QALY threshold of both the sign and scale of changes in overall expenditure will be greater. Subsequent work might enable a quantitative assessment of how the relevant threshold should be adjusted for the scale of the budget impact of technologies appraised by NICE.

Although further work is needed to fully specify the quantitative effect of the scale of the non-marginal impact of new technologies on an appropriate threshold, the qualitative impact seems clear. First, the central estimate of the threshold is likely to be an overestimate for all technologies which impose net costs on the NHS (almost all technologies appraised by NICE have positive incremental NHS costs).[12,99,100] Second, the appropriate threshold to apply should be lower for technologies which have a greater impact on NHS costs.

How does the threshold change with overall expenditure?

The same methods of analysis can be applied to the econometric analysis of the 2007 expenditure and 2007–9 mortality data (see *Analysis of programme budgeting expenditure for 2007/8 and mortality data for 2007/8/9* in *Appendix 2*). This provides an opportunity to consider how the cost per QALY threshold is likely to have changed from 2007 to 2008 as overall expenditure has increased. This can provide some insights into how the threshold might be expected to change over time, for example, overall expenditure

changes and productivity in the NHS might be expected to rise with innovation in health technologies, clinical practice and service delivery. This has implications for a judgement about the appropriate frequency of periodic reassessment of the cost per QALY threshold.

It is not necessarily the case that the threshold will rise with overall expenditure or even with NHS prices. This is illustrated in *Figure 8* where the threshold at budget B1 is represented by k_1. If overall expenditure increases to B2 then, other things being equal, the threshold would also be expected to increase (i.e. k_1 now overestimates the health effects of a change in expenditure at B2).[y] Increasing overall expenditure from B1 to B2 is equivalent to eliminating the same amount of waste in *Figure 8*, i.e. by reallocating resources devoted to activities unproductive to health. Again, other things being equal, the threshold would be expected to increase (k_1 now overestimates the health effects of a change in expenditure at B1) once the waste has been eliminated. However, insofar as the productivity of those activities that are valuable to the NHS also improve through innovation in health technologies, clinical practice and service delivery, the threshold will tend to fall. *Figure 8* illustrates a situation where the effects of eliminating waste (NHS stopping doing things it should not be doing) and, at the same time, improving productivity (NHS getting better at doing things it should do) means that the overall threshold is unchanged.

In making an assessment of whether or not the threshold is likely to increase with the NHS budget it is also necessary to consider whether or not there is discretion over how additional resources can be spent. For example, if any growth in the overall budget is spent on national initiatives or other activities that cannot easily be disinvested, then the additional costs of technologies approved by NICE must be accommodated by displacing other activities elsewhere. Therefore, it is growth in expenditure on more 'discretionary' parts of NHS expenditure and changes in the productivity and input prices of those health care activities which are more likely to be displaced, which are most relevant.

Over recent years much of the real budget growth in the NHS has been devoted to national initiatives that are not easily displaced (e.g. new contracts for GPs and consultants, national waiting time targets, information technology initiatives, etc.).[101] It also includes technology appraisal guidance issued by NICE itself, which has a funding mandate. Therefore, any real growth in what remains may have been more modest, so it is more likely to have been offset by any growth in the productivity of displaceable activities (e.g. drugs, devices, procedures and other services). Similarly, although there has been a general rise in

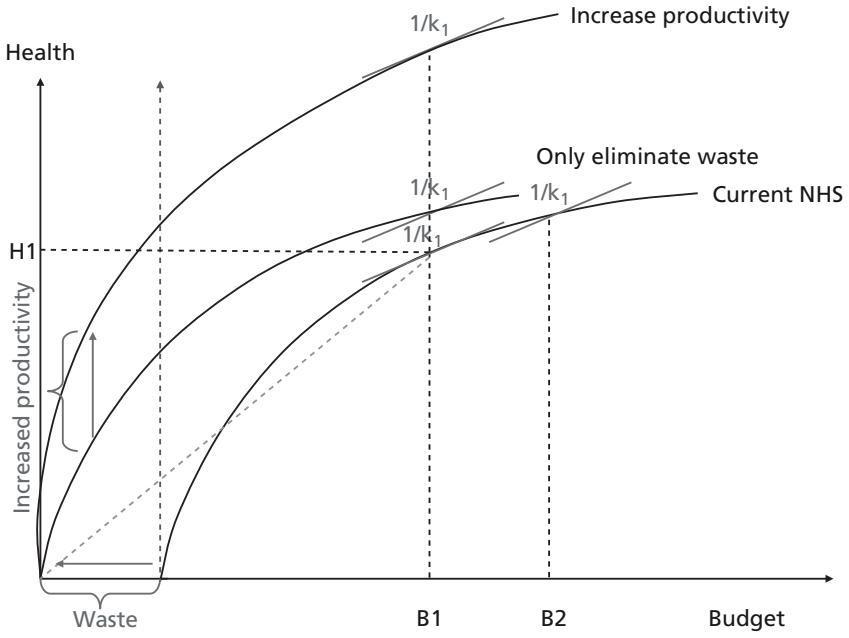

FIGURE 8 Impact of changes in budget and productivity. B1, current budget; B2, increased budget; H1, current level of health; k_1, cost per QALY threshold.

input prices for the NHS, much of this inflation has been driven by staff as well as capital and overhead costs, some of which cannot be easily displaced. What are more relevant are the prices of inputs which could be displaced, an important element of which is drug prices. Although branded drug prices have tended to rise, at the same time there has been generic entry on patent expiry with dramatic reductions in prices for important classes of drugs.[102] Therefore, it is not self-evident that the threshold has grown over recent years, despite real increases in the NHS budget.

The central estimates of the cost per QALY threshold for 2007 and 2008 expenditure years are reported in *Table 33*. In comparing these estimates of the QALY threshold it should be noted that important improvements were made to the classification and collection of PBC expenditure data that took place after the 2006 data were collected. Therefore, the differences in threshold estimates for 2006 and 2007 partly reflect this (see *Comparing the cost of life-year estimates associated with different data sets* in *Chapter 3* and *Comparing the cost of life-year estimates associated with different data sets* in *Appendix 2*) so should not be overinterpreted. The results of the analysis of 2007 and 2008 expenditure are comparable in this respect.

Although overall expenditure increased by 6% between 2007 and 2008 which represented real growth of 2% in 2007 prices,[z] the overall threshold for all 23 PBCs fell by 5% in nominal terms and by 8% in real terms.

The reasons are complex but reflect changes in productivity, which differs across PBCs (changes in outcome elasticities), but also a general reallocation of a change in overall expenditure (changes in expenditure elasticities) towards those PBCs that appear more valuable in 2008.[aa] Given the sources of uncertainty described above, subtle differences between 2007 and 2008 should not be overinterpreted. However, this analysis does suggest that the overall threshold will not necessarily increase with growth in the real or even nominal NHS budget. In conjunction with the results of the analysis described in *How uncertain are the estimates and what are the implications?* it does suggest that the threshold is more likely to fall at a time when real budget growth is flat or falling and PCTs find themselves under increasing financial pressure.

Within the NICE technology appraisal process, the future incremental costs of a technology are expressed in real terms (at current prices) prior to discounting. Therefore, the estimates that are relevant to NICE decisions are: (i) the nominal threshold in the current year;[ab] and (ii) some assessment of the real growth in the threshold over the time horizon where incremental NHS costs are incurred. If there is an expectation of real growth (or fall) in the threshold over time then one way to incorporate this is through a higher (lower) discount rate applied to future cost.[103] Indeed, an expectation of changes in the real threshold over time also suggests something about the social rate of time preference for health, as revealed by budget allocations decisions.[104] However, incorporating an expected growth or decline in the threshold over time by adjusting discount rates is likely to be problematic once it is recognised that the expected incremental costs imposed by a technology are rarely uniform over time.

TABLE 33 Growth in the cost per QALY threshold (2007–8)

PBC grouping	(1) Cost per QALY threshold (2007) (£)	(2) Cost per QALY threshold (2008) (£)	(3) Nominal growth (%)	(4) Cost per QALY threshold (2008), 2007 NHS prices (£)	(5) Real growth (%)
All big four programmes	4549	4872	7	4689	3
11 PBCs (with mortality)	8513	8308	–2	7996	–6
All 23 PBCs	13,554	12,936	–5	12,450	–8

This discussion and the results reported in *Table 33* suggest that there is little empirical support for an assumption that there will have been growth in the nominal threshold between 2008 and 2012.[ab] Growth in the nominal or real threshold seems much less likely in the future with the prospect of reduced budget growth, increased pressures to improve productivity and downward pressure on input prices. As how the nominal or real threshold is likely to change over time cannot be assumed to follow prices or overall expenditure nor empirical estimates or theoretical predictions of a growth in the private consumption value of health (WTP), it becomes especially important to be able to regularly update estimates of the cost per QALY threshold based on routinely available data (see *Future research and improving estimates of the threshold*).

What type of health is forgone by approval of a new technology?

The methods of analysis described in *Chapters 3* and *4* and discussed in this chapter can identify, not only how many QALYs are likely to be forgone across the NHS as a consequence of approving a technology which imposes incremental costs on the NHS, it can also indicate where those QALYs are likely to be forgone and how they are made up, i.e. the additional deaths, life-years lost (unadjusted and adjusted for QoL) and the QoL impacts on those with disease.

For example, in 2011, NICE considered whether ranibizumab (Lucentis®, Roche) for the treatment of diabetic macular oedema should be approved for widespread use in the NHS (TA237).[105] Initially this technology was rejected by NICE on the grounds that, at its current price, it would be unlikely to be cost-effective. In 2012, however, a rapid review of TA237 approved ranibizumab if use was restricted to the most cost-effective subgroup (those with central retinal thickness $\geq$ 400 micrometres) and after a Patient Access Scheme (PAS) for this subgroup of patients was offered (details of the PAS which provides a discount to the NHS is commercial in confidence).[106]

The appraisal and guidance documents[105–109,ac] provide the information required to estimate the additional NHS costs of treating this subgroup of patients each year (see *Appendix 3, Addendum 4: what type of health is forgone by the approval of a new technology?* for details of this example). Up to 44,000 NHS patients would be eligible for treatment with ranibizumab each year based on its licensed indication.[107] However, the subgroup of patients where ranibizumab was ultimately approved is likely to be 23,000 each year. This suggests that the approval of ranibizumab in this subgroup at the original appraisal price set in 2011 (i.e. without a PAS) would impose just over £80M of additional NHS costs for treating the eligible population each year.

Based on the 2008 central estimate of the cost per QALY threshold (£12,936 in *Table 30*) the approval of ranibizumab without a PAS would have been likely to displace 6184 QALYs elsewhere in the NHS. However, the analysis which underpins the threshold estimate can also be used to identify where the additional NHS cost of £80M are likely to impact and where and what type of health effects are likely to be forgone. This is illustrated in *Table 34*. For example, the estimated expenditure elasticities and total PBC expenditure indicates how these costs will tend to affect spending in each of the 23 PBCs [see *Table 34*, column (1)]. The estimated outcome elasticities allow this change in spending in each PBC to be translated into a change in deaths and life-year effects for the 11 PBCs where mortality effects could be estimated [see *Table 34*, columns (2) and (3)]. Applying the estimated proportional effect on the mortality burden of disease to measures of QALY (including the other PBCs) provides an estimate of the total QALY effect of the change in spend in each PBC [see *Table 34*, column (4)].[ad] The comparison of life-year and total QALY effects allows the distinction to be made between QALY effects due the life-year effects of additional deaths and QALY effects due only to QoL [see *Table 34*, columns (5) and (6)].

The results reported in *Table 34* suggests that approval is likely to result in 411 additional deaths [most of which are likely to occur in PBCs circulatory, respiratory and cancer see *Table 34*, column (2)], and 1864 life-years forgone [most of which are likely to occur in PBCs circulatory, cancer and

TABLE 34 Heath forgone across PBCs due to the approval of ranibizumab (£80M budget impact)

PBC		(1) Change in spend (£M)	(2) Additional deaths	(3) Life-years forgone	QALYs forgone		
					(4) Total QALYs forgone	(5) Due to premature death	(6) QoL effects
2	Cancer	3.58	30	300	211	195	16
10	Circulatory problems	6.07	182	928	863	590	273
11	Respiratory problems	3.67	107	129	1,835	80	1754
13	Gastrointestinal	2.56	21	197	351	129	222
All big four programmes		*16*	*340*	*1554*	*3259*	*995*	*2265*
1	Infectious diseases	2.61	6	43	125	29	97
4	Endocrine problems	1.51	5	40	485	26	459
7	Neurological problems	4.78	10	52	873	34	838
17	Genitourinary problems	3.71	18	26	85	17	68
16	Trauma and injuries	6.16	0	0	0	0	0
18 + 19	Maternity and neonates	5.46	0	3	2	1	1
11 PBCs		*40*	*389*	*1717*	*4828*	*1101*	*3727*
3	Disorders of blood	1.65	3	13	175	9	166
5	Mental health disorders	14.29	23	103	762	67	696
6	Learning disability	0.83	0	2	6	1	4
8	Problems of vision	1.55	0	2	34	1	33
9	Problems of hearing	0.70	0	1	112	1	111
12	Dental problems	2.31	0	0	54	0	54
14	Skin	1.57	2	9	16	6	10
15	Musculoskeletal system	2.90	3	14	186	9	176
20	Poisoning and adverse events	0.74	0	2	7	1	5
21	Healthy individuals	2.83	0	1	5	1	5
22	Social care needs	2.40	0	0	0	0	0
23	Other	8.11	0	0	0	0	0
All 23 PBCs		*80*	*411*	*1864*	*6184*	*1197*	*4987*

gastrointestinal – see *Table 34*, column (3)].[ae] However, the impact of approval of this technology on QALYs forgone due to premature death [see *Table 34*, column (5)] only accounts for a proportion of the total QALY effects [see *Table 34*, column (4)]. Most (4987) are associated with QoL forgone during disease [see *Table 34*, column (6)]. These QoL impacts are most likely to occur in PBCs respiratory, neurological and mental health. The PBC level effects in *Table 34* can also be examined at ICD-10 code level, although recognising the caveats discussed in *Chapter 4, Adjusting life-years for quality of life* and *Including quality-of-life effects during disease*.[af] For example, in the respiratory PBC it appears to be chronic lower respiratory diseases (J40–J47) where most additional deaths, life-years and QoL are forgone. In the mental health PBC the additional deaths appear to be associated with disorders due to psychoactive substance use (F10–F19) and mood (affective) disorders (F30–F39) (see *Addendum 4: what type of health is forgone by the approval of a new technology?* in *Appendix 3*). However, it should be recognised that these effects, which are based on the central estimate in *Table 30*, are likely to underestimate the health forgone given the discussion in *How uncertain are the estimates and what are the implications?* and especially in *Impact of investment, disinvestment and non-marginal effects*.

The impact of a reduction in the price of this technology, through either value-based pricing or the PAS that was offered during the rapid review,[106] can also be examined in the same way. The PAS was commercial in confidence but we will consider a scenario where a 30% reduction in NHS costs was applied for this subgroup of patients. Such a discount would be expected to save 1855 QALYs including 126 deaths averted, 559 life-years (359 when adjusted for quality) and QoL effects during disease equivalent to 1496 QALYs, when compared with approval of the technology at the original price (see *Addendum 4: what type of health is forgone by the approval of a new technology?* in *Appendix 3* for more details on this scenario analysis).

In many respects this starts to make 'real' the previously abstract notion that additional NHS costs are the health and opportunities of other unknown NHS patients. The methods of analysis presented in this report go some way to providing an empirically based and explicit quantification of the scale of opportunity costs the NHS faces when considering whether or not the health benefits associated with new technologies are expected to offset the health that is likely to be forgone elsewhere in the NHS. It also starts to make the other NHS patients, who ultimately bear the opportunity costs of such decisions, less abstract and more 'known' in social decisions. As who happens to be known or unknown is only a matter of perspective, time and ignorance,[110] ethical and coherent social decisions require that both should be treated in the same way. The methods of analysis discussed in this chapter have contributed to removing some of the 'ignorance' and making the unknown more real.

Future research and improving estimates of the threshold

There are a number of ways in which this research could be usefully extended based on existing data and the information currently available, most of which have been discussed in previous sections of this chapter. Here we consider the scale of the evaluation problem in this context, examining what, in principle, would be required to resolve some of the key uncertainties discussed in *How uncertain are the estimates and what are the implications?*, before a more detailed examination of how additional routine data and greater access to existing data or data that are likely to become available, might improve estimates of the cost per QALY threshold in the future.

Two important questions remain when attempting to translate the estimated proportionate effects on mortality due to a change in expenditure into a more complete measure of the health effects (see *Chapter 4, Introduction* and *How uncertain are the estimates and what are the implications?*). These are (i) whether the health effects of a change in expenditure in 1 year should be restricted to 1 year or extend over a longer period; and (ii) the extent to which any death averted by expenditure in 1 year returns an individual to the mortality risk of the general population matched for age and gender. The central or 'best' estimates presented in *Chapters 4* and *5* are based on combining the conservative assumption that the health effects of

changes in 1 year of expenditure are restricted to 1 year,[ag] with the more optimistic assumption that any death averted by expenditure in 1 year returns the individual to the mortality risk of the general population.[ah] The combination of assumptions that underpin the central estimates appear to be on balance conservative (see *Table 32* and discussion in *How uncertain are the estimates and what are the implications?*) and are certainly more credible than the implausibly pessimistic or optimistic assumptions that underpin the upper and lower bounds for the threshold that are also reported in *Chapters 4* and *5*. Key questions remain, however. Why can routine data not resolve some of these remaining uncertainties? What would be required to found a central estimate of the cost per life-year or cost per QALY threshold only on econometric estimates rather than, in part at least, resting on judgements about the credibility of these alternative assumptions?[ai]

A brief reiteration of the scale of this evaluation problem and the approaches to estimation that might be taken illustrates the quite profound difficulties and, therefore, the unavoidable need for explicit and accountable judgement and assumptions.[aj]

A longer and more complex lag structure

Of course, a longer and more complex lag structure exploiting the PBC panel data set (i.e. both cross-section and time series observations) that is becoming available over time, could in principle at least, identify the effect of a change in expenditure taking place in year t on health in years $t, t+1, \ldots, t+n$. However, the health effects in subsequent years would need to be isolated from the effects of change in expenditure also occurring in subsequent years (which would also have both immediate and lagged health effects). The health effects of changes in expenditure in year t would need to be isolated from the lagged effects of changes in expenditure in previous years. Depending on the length of time series data available it may be possible to specify and estimate a richer empirical model to account for the lagged health effects of past expenditure and of lagged expenditure effects of past health outcomes.[ak]

Although this is not a problem in principle it does pose difficulties as there are very real limits to the current time series because (i) there are a limited number of observations in the cross-section (152 PCTs); (ii) the definition (and boundaries) of PCTs has changed and has recently changed again with the formation of CCGs; (iii) there are a limited number of years of observation in the time series (especially if lags are long); and (iv) as noted in *Chapters 3* and *5*, the quality of PBC reporting has changed over time (recall that estimates from 2006 and 2007 PBC expenditure were not as comparable as 2007 and 2008). Nonetheless, as the panel data evolves over time there will be more opportunities to explore whether judgements about the duration of effects on mortality can be informed using the type of analysis presented in the report. Insofar as there are later lagged health effects this will tend to reduce the estimate of the cost per death averted, cost per life-year and cost per QALY threshold.[al]

In many respects the problem of duration of mortality effects is a relatively straightforward one compared with the second issue of how changes in mortality (whether immediate or lagged) translate into life-years. In principle, estimating the effect of change in expenditure on life-years is really estimating the effect of changes in expenditure on the survival curves of the population at risk through membership of ICD-10 codes that contribute to each PBC. Even if the issue of lags is set aside, and attention is restricted to mortality effects in the expenditure year, translating these effects into life-years would require observations on the entire survival curve of the at risk population. This poses two profound difficulties: (i) we would need detailed information about the members of the at risk population (patient identifiers); and (ii) sufficient time to follow up the entire cohort from expenditure change to death (also accounting for other changes that are likely to take place during that time). Even if these data were available and such heroic estimation was possible, any estimate would be so historic that it would be of limited policy relevance. This is not a problem unique to this research but remains a problem for all estimates of the YLL due to disease. It may be possible to use external, non-routine, historic data sources where patient identifiers are available to inform a judgement about whether or not changes in mortality in critical ICD-10 codes (e.g. respiratory) tend to return patients to mortality risks similar to those of the general population. If historic evidence suggests that they remain at higher mortality risk it might indicate the likely scale of

overestimation if life-year effects are based on the mortality risk of the general population. However, this would not be without major problems of distinguishing causality from selection effects.

The evolving panel data do have another advantage that could be exploited in the future. Currently it is only cross-sectional variation (i.e. between PCTs) that contributes to the estimates of outcome elasticities. This means that changes in expenditure that all PCTs tend to make together, that might have very large health effects (they all tend to invest in obviously valuable activities at the same time) or limited health effects (they all disinvest in some activities that are not valuable at the same time), may not be fully reflected in the current estimates.[am] However, using variation in expenditure and outcome in both cross-section and time series could more confidently pick up the full effects of simultaneous investment and disinvestment. The likely net effect on the overall threshold is unclear and will depend on whether PCTs tend to be more co-ordinated when investing in valuable activities (tending to reduce the threshold) or when disinvesting in ineffective ones (tending to increase the threshold).[an]

Simultaneous estimation across programme budget categories

Although expenditure equations are estimated for all 23 PBCs and outcome equations for the 11 PBCs where there are sufficient mortality data, these are estimated separately; each accounting for other PBC expenditure and other PBC need (see *Chapter 3, Modelling framework*). The correlations between expenditure and outcome elasticities within each PBC were also estimated by repeatedly resampling the data set and re-estimating expenditure and outcome elasticities (see *Appendix 2, The correlation between the outcome and expenditure elasticities*). Although the estimate of the overall threshold accounts for changes in expenditure across all 23 PBCs with health effects estimated in 11 and inferred in the others, it is possible that changes in expenditure in one PBC may have health effects in others. Although total deaths across all 23 PBCs are accounted for, unless the possible 'external' mortality effects in other PBCs happen to be associated with variation in expenditure in those PBCs then these health effects will not be reflected in the estimated outcome elasticities. This seems likely to underestimate the total health effects of changes in expenditure unless positive health effects are thought to be offset by expenditure in one PBC damaging health outcome in others (e.g. adverse events associated with treatment or other iatrogenic effects).[ao] To account properly for these possible effects would require estimating the interaction of changes in expenditure in each PBC on all the others while still accounting for possible endogeneity. Unfortunately, with only 152 observations in the cross-section (PCTs), this type of simultaneous estimation is currently not feasible.

Throughout *Chapters 3–5* we have not imputed health effects for PBC 23 (GMS) or procedural ICD-10 codes on the grounds that the health effects of this type of expenditure will appear in ICD-10 codes that contribute to other PBCs. However, the health effects of this type of expenditure (PBCs 22 and 23) will only be reflected in the estimated outcome elasticities insofar as the variation in outcomes reported in other PBCs, due to variation in GMS expenditure, happens to be associated with variation in expenditure in those other PBCs. Therefore our approach to GMS (and social care, PBC 22) expenditure is likely to be conservative with respect to overall health effects; tending to overestimate the cost per life-year and cost per QALY threshold.

Exogenous shocks and quasi-experiments

One response to these difficulties would be to look for exogenous budgetary shocks to the whole health-care system and then estimate the health effects of the shock at a macro level. In principle this is very attractive as it would avoid all the difficulties of endogeneity and identifying valid instruments, exploring sensitivity and structural uncertainty. If a complete measure of health outcome was available at a health system level it would also avoid much of the complexity of working at a PBC and ultimately at ICD-10 code level.

Unfortunately, there are a number of difficulties. Although the NHS budget is set each year through an essentially political process (so each year's change in budget might be regarded as an exogenous shock), insofar as public expenditure decisions are to some extent influenced by public sector performance,

then these apparent 'shocks' are endogenous in a very similar way to PCT expenditure decisions about particular PBCs, but just at a higher level of aggregation. However, even if some arbitrary exogenous change to overall expenditure could be identified there are other serious difficulties. There is no comprehensive measure of outcome relevant to all NHS activities currently reported. This has two implications: (i) the mortality data that are available are only relevant to approximately 36% of a change in overall expenditure (see *Which programme budget categories matter most?*); and (ii) how mortality translates into life-years and QALYs depends critically on where those effects occur (the ICD-10 codes that contribute to each PBC). In addition, there are very good reasons why one would expect covariates (especially measures on need) and instruments to differ between different programmes of care. For all these reasons this research has focused on using routinely available data at its lowest level of aggregation.

By doing so we not only provide an estimate of a threshold based on a more complete measure of health effects, we are also able to indicate what type of health is affected and where they are most likely to occur. This provides a means to update estimates of the threshold should other aspects of social value be applied to measures of health or other aspects of social value be included in the future (e.g. consumption and other public expenditure effects). For example, any 'weights' that might be assigned to different types of QALY gains or consumption and other public expenditure effects associated with health effects and the patient characteristics associated with ICD-10 codes (e.g. QALY burden, YLL or other patient characteristics, such as age and gender) can be included in the current framework and a threshold re-estimated for 'weighted' QALYs or, give an estimate of the consumption value of a QALY, a threshold benefit–cost ratio that includes consumption as well as health effects.

Evolving programme budget category data

Each year offers another wave of PBC expenditure data which means that a potentially useful panel data set is developing. This offers some useful opportunities that have been described above. However, with only 152 PCTs in the cross-section, there is a limit to how much of the remaining uncertainty might be resolved. The utility of this evolving panel will also be limited by the formation of CCGs rather than PCTs as an important locus of expenditure decisions. Changes in PCT boundaries and the formation of CCGs will make the time series problematic unless CCGs can be mapped to previous PCT boundaries. However, updating expenditure and outcome elasticities based on variation in expenditure and outcomes across CCGs would be possible (it would provide more observations in the cross-section) so long as PBC expenditure and mortality outcomes are reported at CCG level.

Of course it would also be useful to be able to observe PBC expenditure at a lower level of aggregation (ideally at ICD-10 code) as this would avoid the assumption necessary to allocate PBC level effects to ICD-10 codes based on either estimates of the size of the at risk population or the crude (unadjusted for covariates) contribution to variance in PBC expenditure. As the only expenditure data that are available by ICD-10 code (and therefore PBC) for each PCT are HES-based estimates of cost, the relevance of measures of contribution to variance in PBC expenditure depends on what proportion of PBC costs are accounted for by HES. However, HES costs are only a small component of total PBC expenditure and contribute very little to the variability in PBC expenditure across PCTs especially when considering PBCs where mortality effects could not be estimated (see *Chapter 4, Including quality-of-life effects during disease* and *Chapter 4*, notes an and au). Greater disaggregation within PBCs would be particularly useful as the examination of information routinely collected by PCTs was not particularly helpful in identifying what investment and disinvestments within a PBC explain the variation in expenditure across PCTs (see *Addendum 2: the role of data on local NHS decisions* in *Appendix 3*).

Extending measures of health outcome

Currently the only routinely collected health outcome data that can be matched to expenditure by PBC at PCT level is mortality. For this reason outcome equations could only be estimated for 11 of the 23 PBCs. As discussed in *Chapter 4, Adjusting life-years for quality-of-life* and *Including quality-of-life effects during disease*, this represents only one aspect of health outcome and is not particularly relevant to many disease categories and much of the care that the NHS offers, when the primary purpose is to improve health

experience and QoL rather than to extend survival. Therefore, the estimated proportionate effects of expenditure on the QALY burden of disease in these 11 PBCs were used as a surrogate for proportionate effects in the others, i.e. assuming that the proportionate effects that can be observed will be similar to those that cannot (see *Re-estimating the cost per quality-adjusted life-year threshold using more recent data*).

Of course, with access to a more complete measure of health outcome, which is routinely reported at PCT level and that can also be associated with PBC expenditure, it would be possible to use the same econometric methods to estimate the health effects of a change in expenditure across all PBCs, rather than imputing them in those PBCs where mortality is not the most relevant measure of health outcome.

The English NHS PROMs programme was introduced in 2009 and routinely collects self-reported health status of patients receiving surgery for four elective procedures: knee replacement, hip replacement, groin hernia repair and varicose vein surgery. The data that are collected include both condition-specific questions (the Oxford Hip Score, Oxford Knee Score and the Aberdeen Varicose Vein score; no condition-specific instrument is available for hernia) as well as the generic instrument, the EQ-5D (both the EQ-5D profile, and the patient's global assessment of their health, the European Quality of Life-visual analogue scale (EQ-VAS). Patient-level data from the PROMs programme are freely available and can be linked to the HES database which provides a potential link to PBCs. Standardised reports on the PROMs data, including the average (case-mix adjusted) performance of providers, are regularly published by the NHS IC, currently on a quarterly basis. Although currently offering very limited coverage for our purposes, there are plans to extend the PROMs programme in the future, with work under way or being planned around the potential use of PROMs in a wide range of long-term conditions, primary care, in cancer survivorship, cardiovascular services, musculoskeletal and cosmetic surgery.

In *Appendix 2*, *Application of method to other non-mortality-based outcome indicators* we demonstrate how the econometric methods set out in *Chapter 3* can be extended to these other non-mortality-based outcome measures. EQ-5D utility scores (pre and post an operative procedure) from the PROMs programme are used to generate a non-mortality-based outcome measure, which we use to estimate our outcome model. Although the Department of Health does not report the number of patients undergoing an eligible operation by commissioner (PCT) it was possible to use the HES data set to obtain this information. Routine reporting of procedure or intervention by commissioner in the PROMs data set would seem a simple but important and valuable extension, especially as data are extended to primary care where HES cannot be used to substitute for this omission.

With data for both the average health gain per operation and the number of operations, we were able to estimate 'the health gain per head of population' for hip and knee replacements as defined above. This estimated outcome elasticity can then be used as an outcome measure for changes in expenditure in the 'problems of the musculoskeletal system' programme (i.e. PBC 15).[ap] However, translating the short-term impact of an intervention on QoL, which can be estimated from PROMs data, into an estimate of the longer-term effects on QoL remains problematic.

Table 72 in *Appendix 2* reports the estimated outcome equation for PBC 15 (musculoskeletal system) using the PROMs-based outcome measure. The result is intuitively plausible; an increase in expenditure improves health outcomes but, for a given spend, more need reduces the gain. The diagnostic statistics suggest that expenditure is endogenous and that the instruments are valid. They also suggest that the instruments are relevant and there is no evidence that the instruments are weak. Therefore, it is feasible to extend our modelling approach beyond those programmes with mortality outcomes should PROMs be extended more widely. Insofar as PROMs can contribute to a more secure estimate of the overall cost per QALY threshold in the future, the sensitivity analysis discussed in *Which programme budget categories matter most?* starts to indicate where this type of information might be most useful.

Musculoskeletal is an important PBC, accounting for over 5% of a change on overall expenditure and almost 5% of the change in health outcomes. However, of those PBCs without mortality outcomes, it is PBC 5 (mental health) that is most critical (see *Table 31* in *Which programme budget categories matter most?*).

Measures of anxiety and depression are already routinely collected before, during and at the end of interventions as part of Improving Access to Psychological Therapies (IAPT), which is an NHS programme rolling out services across England offering interventions approved by NICE for the treatment of depression and anxiety disorders. By March 2011 IAPT services were offered in 142 of 151 PCTs. A requirement of the programme is to complete the Patient Health Questionnaire-9 (a measure of depression)[110] and Generalised Anxiety Disorder Assessment-7 (a measure of anxiety).[111] Both of these disease-specific measures can be linked to Short Form questionnaire-20 items and further work could, in principle, link these scores to EQ-5D. This is a rich, valuable and evolving data set which potentially provides much of the information required to extend the econometric modelling to the mental health PBC. The experience with PROMs data suggests that this would be feasible, and the analysis in *Which programme budget categories matter most?* indicates that this could make a significant contribution to strengthening the assessment of the overall threshold. It would also contribute to an assessment of the cost-effectiveness of this programme both nationally and by PCT, which would be of value in its own right. Unfortunately, despite the collection of these data for every patient encounter for a number of years, unlike PROMs, these data have not yet been made publicly available.[aq] Of course, the services offered by the IAPT programme do not account for all the variation in expenditure in the mental health PBC. Nevertheless, access to data that have been and continues to be collected by practitioners and NHS patients, could provide estimates of changes in mental health outcomes due to changes in some types of mental health expenditure, which would be a significant advance.[ar]

Incidence and duration of disease

Chapter 4, From mortality to life-years sets out the series of steps required to translate mortality effects into life-years while taking account of competing risks or counterfactual deaths. This analysis used ONS data on deaths by age and gender in the ICD-10 codes that contribute to each PBC, as well as LEs by age and gender for the general population. Some information was also required about the age and gender distribution of the population at risk in the ICD-10 codes that contribute to each PBC (see *Tables 11* and *12*). In *Chapter 4, Years of life lost and accounting for counterfactual deaths* this was based on age and gender distribution of estimates of incidence from the WHO GBD study. The same information was also used in *Chapter 4, Quality of life based on the general population* to adjust life-years for the QoL norms of the general population by age and gender. In *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* the measures of QALY burden of disease also used information about the duration as well as incidence of disease from the same GBD study. These estimates, published in 2008, were based on 2004 UK data and proved to be the best available source of this type of information given the resources available for this research. However, the GBD study has recently been updated with the findings first publicly presented in December 2012.[113] The methodology of the new study as well as sources of information used have been much improved and any subsequent research on the threshold could integrate these new and improved estimates.

However, the GBD study is not the only potential source of information about estimates of incidence of disease by age and gender and disease duration across all the ICD-10 codes that contribute to the 23 PBCs. For example, the Clinical Practice Research Datalink (CPRD) [previously named General Practice Research Database (GPRD)] contains over 3 million active patient records drawn from approximately 400 primary care practices in the UK. CPRD is jointly funded by the NHS National Institute for Health Research (NIHR) and the Medicines and Healthcare products Regulatory Agency. The database has clinical and prescription data and can provide information to support pharmacovigilance (indication, utilisation, and risk/benefit profiles of drugs) and formal pharmacoepidemiological studies, including information on demographics, medical symptoms, therapy (medicines, vaccines, devices) and treatment outcomes.

Although this research was not funded to purchase access to CPRD data, we were able to examine a sample which comprised 22,313,086 rows/patient–ICD-10 events (three digit) representing 4,229,910 patients with data on diagnosis of diseases observed between 1 January 2006 and 24 June 2011 (see *Addendum 1: data sources* in *Appendix 3*). Although CPRD data could, in principle, provide the type of information required, the difficulties faced and the interpretation of the sample of data in the form available to us meant that it was not directly useful. The particular problems faced included: (i) read rather than ICD-10 codes reported in the data set, although mapping is and was possible; (ii) being able to identify when an episode of disease ended; (iii) estimating duration of disease from the sample of data when observations were censored by the limited years of data available to us; and (iv) confidently identifying incident patients in diseases of longer duration despite 2 years of washout prior to extracting the sample. CPRD is quite clearly a rich and valuable data set. However, our experience suggests that, to make best use of these data, specialist knowledge and experience of these data is really needed as well as access to a much larger sample than we were able to acquire with the limited resources available. Therefore, although CPRD could well help to improve estimates of incidence by age, gender and duration of disease, it would require additional well-resourced research including excess to specialist expertise and experience with this particular data set.

Recommendations for research

The priorities for further research that may be feasible based on data which are, or will become, available can be summarised as follows:

1. Any growth in the nominal or real threshold cannot be assumed (see *Impact of investment, disinvestment and non-marginal effects* and *How does the threshold change with overall expenditure?*), so it will be important to update estimates of the threshold with more recent and future waves of expenditure and mortality data.
2. If other aspects of social value are applied to health benefits of a new technology they must also be attached to the type of health that is likely to be forgone due to additional NHS costs. The methods developed in this research can be extended to allow the same weights to be also attached to the type of health that is forgone and estimate the wider social benefits that are likely to be lost when the NHS must accommodate the additional costs of new drugs.
3. We have demonstrated that these methods of analysis can be applied to QoL data collected as part of PROMs. This type of analysis could be applied to these data in key PBCs as PROMs is rolled out providing some evidence about the QoL effects of changes in PBC expenditure.
4. A key PBC is mental health. Currently, outcomes data that could be linked to measures of QoL are routinely collected in primary care. In principle, the same methods of analysis can be applied to these data once they are made available providing some evidence about the QoL effects of changes in mental health expenditure.
5. Improved and more recent estimates of incidence (by age and gender) and duration of disease will soon be available from the recently published updated GBD study. These data could be used when the threshold is re-estimated for later waves of expenditure data. Alternatively, estimates could be based on CPRD data. However, our experience suggests that utilising CPRD data would need research that is well resourced with access to specialist expertise and experience with this particular data set.
6. Estimating a more complex lag structure based on the evolving panel data would provide valuable evidence about the duration of the health effects of changes in expenditure. The recent release of census data for 2011 may allow a panel model to be estimated allowing better control for unobserved heterogeneity across PCTs as well as exploiting variation in outcomes, expenditure and other covariates over time. There are, however, significant challenges including the formation of CCGs in 2013, which will make the time series problematic for waves of expenditure and outcomes after 2012.
7. If PBC expenditure and outcome data are available at CCG level (as well as covariates and suitable instruments), it might become possible to estimate outcome and expenditure equations simultaneously across PBCs. This would enable more of the likely health effects of changes in expenditure to be reflected in the analysis.

Conclusions and implications for practice

The methods of analysis presented here go some way to providing an empirically-based and explicit quantification of the scale of opportunity costs the NHS faces when considering whether or not the health benefits associated with new technologies are expected to offset the health that is likely to be forgone elsewhere in the NHS. As such, it provides a basis for determining the appropriate threshold for NICE decisions as well as those made centrally by the NHS and Department of Health more generally.

Since 2004, NICE has used a threshold range of £20,000–30,000 per QALY. It has been widely recognised for many years that this range is not based on evidence. The central estimate of the cost per QALY threshold (£12,936 per QALY based on 2008 expenditure) suggests that the upper bound to this range is almost certainly too high and the lower bound is also likely to be an overestimate (see *Re-estimating the cost per quality-adjusted life-year threshold using more recent data*). For example, the analysis of the uncertainty associated with the estimated expenditure and outcome elasticities indicates that the chance the threshold is < £20,000 per QALY is 89% and the chance that it is < £30,000 is 97% (see *How uncertain are the estimates and what are the implications?*).

The central estimate is based on identifying a preferred analysis at each stage based on the analysis that made the best use of available information, whether or not the assumptions required appeared more reasonable than the other alternatives available, and which provided a more complete picture of the likely health effects of a change in expenditure. Although other assumptions and judgements are possible that retain some level of plausibility, they do not all favour a higher threshold. Indeed, when considered together, they suggest that on balance the central estimate of £12,936 is, if anything, likely to be an overestimate (see *How uncertain are the estimates and what are the implications?*).

Although there is substantial uncertainty associated with the estimate of the overall threshold (including parameter, structural and other sources of uncertainty), a policy threshold set at its mean or expected value may be inappropriate because the consequences for the NHS of overestimating the threshold are more serious than underestimating it (see *How uncertain are the estimates and what are the implications?*). In principle, a policy threshold (a single value that can be compared to an ICER) should be set below its mean value to take account of the non-linear relationship between the threshold and the additional NHB offered by a technology.

The analysis of PCTs that are under more or less financial pressure (above or below their target resource allocation) starts to indicate the quantitative effect of the scale of the non-marginal impact of new technologies on an appropriate threshold (see *Impact of investment, disinvestment and non-marginal effects*). It suggests that the central estimate of the threshold is likely to be an overestimate for all technologies which impose net costs on the NHS (almost all technologies appraised by NICE have positive incremental NHS costs), and that the threshold might be lower for technologies which have a greater impact on NHS costs.

The research found no evidence that the threshold had increased with real growth in the NHS budget or with NHS prices (2007–8) (see *How does the threshold change with overall expenditure?*). There is little empirical support for an assumption that there will have been growth in the nominal threshold between 2008 and 2012. As how the nominal or real threshold is likely to change over time cannot be assumed to follow prices or overall expenditure, nor empirical estimates or theoretical predictions of a growth in the private consumption value of health (WTP), it becomes especially important to be able to regularly update estimates of the cost per QALY threshold based on routinely available data (see *Future research and improving estimates of the threshold*).

The methods of analysis can not only identify how many QALYs are likely to be forgone across the NHS as a consequence of approving a technology which imposes incremental costs on the NHS, they can also indicate where those QALYs are likely to be forgone and how they are made up, that is the additional deaths, life-years lost (unadjusted and adjusted for QoL) and the QoL impacts on those with disease (see *What type of health is forgone by approval of a new technology*?). In doing so the study starts to make the other NHS patients, who ultimately bear the opportunity costs of such decisions, less abstract and more 'known' in social decisions. As who happens to be known or unknown is only a matter of perspective, time and ignorance, ethical and coherent social decisions require that both should be treated in the same way. These methods contribute to removing some of the 'ignorance' and making the unknown more real.

These methods also allow other aspects of health outcome to be incorporated in the estimate of the threshold. This has implications should a system of value-based pricing for new prescription pharmaceuticals be introduced, which may include some additional weight for health benefits in diseases which impose a large health burden and/or where there are wider social benefits for patients, their carers and the wider economy. The methods developed in this research will allow the same weights to be also attached to the type of health that is lost and estimate the wider social benefits that are likely to be lost when the NHS must accommodate the additional costs of new drugs.

The methods of analysis can be used as a framework for further empirical work as additional and more appropriate data emerge in the NHS (see *Future research and improving estimates of the threshold*). They also offer a basis for threshold estimation in other health-care systems which face constraints on the growth of health-care expenditure and use CEA to inform resource allocation decisions.

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All views expressed here, and any errors, are entirely the responsibility of the authors.

Contributions of authors

All of the named authors below contributed to the development of the research questions, study design and implementation (including membership of the study management group), analysis and/or interpretation of data and submission of the final report. Contributions to particular elements of the study are described below.

Karl Claxton (Professor of Economics, University of York) was a co-applicant, and led the overall design of the study, interpretation of results and writing of the report.

Steve Martin (Researcher, University of York) was a co-applicant and undertook and wrote up the econometric analyses detailed in *Chapter 3* and *Appendix 2*.

Marta Soares (Research Fellow, University of York) undertook the analyses extending the econometric analysis on mortality changes to broader health effects on QALYs (see *Chapter 4* and *Appendix 3*).

Nigel Rice (Professor of Health Economics, University of York) was a co-applicant and contributed to the design, interpretation and write-up of the econometric analysis.

Eldon Spackman (Research Fellow, University of York) designed and undertook the systematic review (see *Appendix 1*) and contributed to analyses linking mortality changes to broader health effects on QALYs.

Sebastian Hinde (Research Fellow, University of York) designed, undertook and wrote up the systematic review (see *Appendix 1*), and contributed to analyses linking mortality changes to broader health effects on QALYs.

Nancy Devlin (Director of Research, Office of Health Economics) was a co-applicant and led the design and write-up of the review of local data availability.

Peter C Smith (Professor of Health Policy, Imperial College London) was a co-applicant, and contributed to the design and interpretation of all aspects of the analysis.

Mark Sculpher (Professor of Health Economics, University of York) was the principal applicant, chaired the study management group and contributed to the design, interpretation and write-up of all aspects of the analysis.

Notes

Chapter 2

a. This is the case as long as all incremental costs are health-care system costs or, as currently, the perspective adopted by NICE is commonly restricted to the health-care system. If a broader perspective was to be adopted and, insofar as there are some incremental costs (or benefits) of adopting a technology that fall on private consumption, then v does become relevant to decision-making because it represents the value of these consumption effects in terms of health. In these circumstances it would be inappropriate either to compare an ICER which included consumption effects to k (because consumption costs do not displace health in the NHS), or to compare it to v (because some of the costs do not displace private consumption but displace health at rate k). The ratio of k/v represents the value of NHS resources relative to private consumption. Observing $k < v$ would suggest a positive shadow price on NHS resources and public expenditure more generally (i.e. it would indicate that a public sector £ is scarce relative to a private £). See Claxton *et al.*[37] for a more extended treatment of perspective, the implications for decision rules and the centrality of an estimate of the threshold, k.

Chapter 3

a. Strictly speaking, these local health authorities are primary care organisations (PCOs), but the vast majority of these are 'trusts' and we retain this terminology throughout.

b. Owing to data limitations the cited studies were only able to relate expenditure in period t to mortality in periods t, $t-1$, and $t-2$ combined. Such studies assumed that PCTs had reached some sort of equilibrium in the expenditure choices they make and the outcomes they secure.

c. Owing to data availability constraints previous studies had to relate expenditure in period t to mortality data in periods t, $t-1$, and $t-2$ combined. Implicitly this assumes that data represent a quasi-long-run equilibrium position, and that relative expenditure levels and health outcomes within each PCT have been reasonably stable over a period of time.

d. Comparable data for each programme budget subcategory is shown in *Table 91* in *Appendix 2*.

e. These revisions are documented in *Appendix 2*, *Programme budgeting expenditure, 2003/4–2008/9*.

f. Expenditure on, for example, community care, accident and emergency (A&E), ambulance services and outpatients can be difficult to attribute a particular PBC. Critical care, rehabilitation and specialised commissioning across care settings will also be difficult to attribute to a particular programme.

g. This cost adjustment reflects the fact that health economy input prices vary considerably across the country and, for some inputs, are up to 40% higher in London and the south east of England than elsewhere. We have used a weighted average of the three market forces factor (MFF) indices for Hospital and Community Health Service (HCHS), for prescribing, and for general medical services (GMS)/primary medical services (PMS) to adjust the raw expenditure figures in table 2 for local input prices.[74]

h. This needs adjustment incorporates the AREA resource allocation formula for HCHS.[76]

i. The approach adopted here is extendable in principle to other non-mortality-based outcome indicators. We illustrate such an application in *Appendix 2, Application of method to other non-mortality-based indicators* where we use European Quality of Life-5 Dimensions (EQ-5D) utility scores pre and post an

operative procedure from the patient-reported outcome measures (PROMs) programme to generate a non-mortality-based outcome indicator, and we use this indicator to estimate our outcome model.

j. One exception to this is the mortality rate for the trauma and injuries programme where initially only SMRs were available.

k. Details of the construction of all instruments are shown in *Table 92* of *Appendix 2*.

l. This incorporates the Combining Age-Related and Additional Needs (CARAN) formula for HCHS and reflects need across all health-care services.

m. However, we do experiment replacing and supplementing this all service measure of need with more programme-specific measures where these are available (e.g. the diabetes and epilepsy prevalence rates).

n. Although need is a function of mortality/morbidity in the resource allocation formula, the relationship is not sufficiently strong enough for us to be concerned about the endogeneity of the need in any individual care programme.

o. Instrumental variable estimation of say, *Equation 8*, involves a first-stage regression of the endogenous expenditure variable, x, on the instrument, z, and the set of exogenous regressors in *Equation 8*, n. Predictions, $\widehat{x}$, from this model can then be included in a second-stage regression of *Equation 8* as a replacement for the endogenous regressor, x.

p. Note that the mortality data precedes expenditure in these models. This was due to data limitations at the time of the study.

q. Initial modelling work employed the Department of Health's resource allocation model of the need for health care based on the AREA report.[76] Subsequent refinements and updates to this model employed the implementation of the CARAN model[74] and the initial findings of a person-based resource allocation (PBRA) study.[86]
The use of these alternative models for the need for health care was explored.

r. An exception to this is expenditure on GMS/PMS (PBC 23a) which is adjusted using the GMS/PMS MFF.

s. Refer to *Appendix 2*, *Table 69*.

t. Using the CARAN model.[74]

u. In addition to respiratory and neurological programmes the other programmes where the all service measure of need was replaced are: *endocrine*: Index of Multiple Deprivation 2007 data set (IMD2007) and diabetes prevalence rate; *genitourinary*: lone parent households; *infectious diseases*: IMD2007 and HIV need per head and its square; *maternity and neonates*: proportion born outside EU and proportion of population with no qualification aged 16–74 years. For *trauma and injuries*, the all service measure of need was supplemented with the proportion of households without a car and proportion of full-time students.

v. The four programmes are endocrine, infectious diseases, maternity/neonates and trauma/injuries.

w. The Kleibergen–Paap F-statistic is very close to the target value of 10 for both the genitourinary and infectious diseases outcome models.

x. These are *endocrine*: all service measure of need and diabetes prevalence rate; *neurological*: epilepsy prevalence; *GMS/PMS*: proportion of lone pensioner households; *trauma/injuries*: proportion of population working in agriculture.

y. Full details of these calculations can be found in *Appendix 2*, *Tables 83* and *84*.

z. The CARAN measure of service need.

aa. The amendments are *respiratory diseases*: all service need and all service need squared; *endocrine*: IMD2007 and diabetes prevalence rate; *genitourinary*: lone parent households; *infectious diseases*: IMD2007 and HIV need per head and its square; *maternity and neonates*: all service need and proportion born outside EU and proportion of population with no qualifications aged 16–74 years.

ab. These are *infectious diseases*: HIV need and its square; *endocrine*: all service measure of need, its square and diabetes prevalence rate; *genitourinary*: all service measure of need and proportion of residence born outside EU; *maternity/neonates*: maternity measure of need; *GMS/PMS*: all service measure of need, proportion of residents reporting permanent sickness (aged 16–74 years), proportion of lone pensioner households and proportion in professional occupations; *trauma/injuries*: proportion of population working in agriculture.

ac. Expenditure on, for example, community care, A&E, ambulance services and outpatients can be difficult to attribute to a particular PBC. Critical care, rehabilitation and specialised commissioning across care settings will also be difficult to attribute to a particular programme.

ad. With the index for 1987/8 set equal to 100, then 2005/6 = 240.9, 2006/7 = 249.8, 2007/8 = 257.0 and 2008/9 = 267.0.[87]

ae. Such studies assumed that PCTs had reached some sort of equilibrium in the expenditure choices they make and the outcomes they secure.

Chapter 4

a. Although 3 years of mortality data are used in the analysis of each year of expenditure, these are averaged to an annual value prior to estimating outcome elasticities. Therefore, the estimated outcome elasticities represent the proportionate effect on mortality in 1 year due to a proportionate change in expenditure.

b. This does assume that the proportionate effects on mortality due to changes in expenditure are similar for mortality that is, and is not, recorded at PCT level. This seems more reasonable than assuming no effect of expenditure on mortality that happens not to be recorded at PCT level.

c. The estimated outcome elasticity for PBC 16 (trauma and injuries) was zero for 2006 and could not be estimated for 2008 expenditure. Therefore, this PBC does not contribute any changes in health outcomes, although the changes in this expenditure are included in subsequent estimates of cost per life-year and QALY thresholds. However, there was a very limited coverage of mortality data recorded at PCT level and the expenditure data for this PBC. In addition, the mortality data that was available (ICD-10 codes S72, S02, S06 and T90) was less likely to be associated with changes in expenditure in this PBC and more likely to be associated with changes in expenditure in others. Consequently, the health effects of changes in expenditure in PBC 16 may be underestimated.

d. The YLL available from NHS IC represented all deaths from maternity and all deaths under 28 days across PBCs. The coverage factor [0.68 in column (1) of *Table 8*] adjusts this YLL to represent maternity and all deaths < 1 year across PBCs. The calculation is described in *Appendix 2*, *Table 37*.

e. This is the LE that reflects the age distribution of the general population, i.e. the average of the sum of the LEs conditional on age, over the current age distribution. It will always be higher than LE at birth.

f. These 'counterfactual' deaths will occur in the other PBCs insofar as all deaths are recorded in an ICD-10 code. Therefore, we take account of the unavoidable fact that everyone must die of something at some time. For example, even if all observed cancer mortality was avoidable and could in principle be eliminated with sufficient expenditure, lives would not be 'saved' but deaths delayed and reallocated to other causes. Note that the outcome elasticities are based on PBC mortality that is sensitive to changes in expenditure (i.e. is avoidable) at the margin so no assumptions about how much of the PBC mortality is avoidable is required.

g. Simply taking the difference between a fixed LE and the age at death of deaths that occur below LE and ignoring those death that occur above LE, would only provide the correct figure if it is reasonable to assume that no deaths would have otherwise occurred prior to LE (so all 'normal' deaths must occur at LE) and that there are no deaths (survivors) beyond LE in the at risk population, i.e. all deaths below LE are excess deaths and there are no excess deaths above LE.

h. If risk increases over the disease duration more deaths would be observed in groups that have been prevalent for some time (i.e. are older) than those that are incident. Also if PBC-related mortality is higher for older age groups they will be overrepresented in observed deaths compared with a matched normal population. For both reasons LE, YLL and cost per life-year would be overestimated using age at death as a proxy for the age distribution of the at risk population.

i. A higher (lower) LE will mean that there are more (less) deaths below LE, each generating more (fewer) YLL and fewer (more) deaths above LE each generating fewer (more) YLG.

j. Although this research was not funded to purchase access to General Practice Research Database (GPRD) data we were able to examine a sample of it which comprised 22,313,086 rows/ patient-ICD-10 events (3 digit) representing 4,229,910 patients with data on new diagnosis of diseases observed between 1 January 2006 and 24 June 2011 (see *Addendum 1: Data sources* in *Appendix 3*). Although GPRD data could, in principle, provide this type of information the difficulties of reliability, face validity and interpretation of the sample data in the form available to us meant that it was not directly useful. We discuss the potential value of other sources of information, including GPRD in *Chapter 5*.

k. We are aware that the 2000–2 WHO GBD study and the update which was published in 2008 using 2004 data has itself recently been updated. However, the report and tools were not publically available at the time this research was conducted. We discuss the potential of future sources of information in *Chapter 5*.

l. The WHO, through the National Burden of Disease toolkit, reports UK-specific information about the incidence and duration of sequelae associated with different types of disease by age and gender. As it is possible that a patient may experience more than one of the types of sequelae reported in GBD we use the gender and age distribution of the sequelae with the highest prevalence (evaluated as incidence x duration) to evaluate the age and gender distribution within each disease, i.e. the minimum estimate of prevalence consistent with these figures (see *Years of life lost and accounting for counterfactual deaths* and *Addendum 1: Data sources* in *Appendix 3*).

m. Throughout the analysis in *Chapter 4* mortality, life-years and QALY were not assigned to procedural ICD-10 codes (*Appendix 3, Years of life lost and accounting for counterfactual deaths*) as these are likely to be evident in other ICD-10 codes related to the procedure. This means that no health effects are associated with PBC 22 social care (which only includes procedural ICD-10 codes), although changes in expenditure on PBC 22 are included. This is likely to overestimate the threshold because any health effects associated with PBC 22 will not be reflected in the estimated outcome elasticities of other PBCs unless the effects happen to be correlated with changes in expenditure in those other PBCs.

n. The average of the sum of the YLLs for every observed death where the YLL for each observed death is the difference between age at death and LE conditional on age of death.

o. In the absence of information about the age distribution of excess deaths this assumes that the average YLL associated with observed and excess deaths are similar. Insofar as excess deaths are thought likely to generate more YLL than observed deaths the number of excess deaths will tend to be overestimated. This would tend to underestimate the cost per excess death averted. However, the cost per life-year estimates remain unchanged and do not require such an assumption.

p. The impact of the age distribution of deaths and the age distribution of the at risk population (summarised as LE) on the calculation of excess deaths is not always obvious as both will affect the numerator (net YLL) as well as the denominator (average YLL per death) in this calculation.

q. Observed PBC mortality that is sensitive to changes in expenditure can be regarded as 'avoidable' and it is only this mortality that contributes to the estimates of outcome elasticities (not all observed mortality is necessarily avoidable and sensitive to expenditure – such mortality will not contribute to the estimates). Not all observed mortality is excess when compared with the counterfactual population but this is unrelated to the question of how sensitive it is to expenditure, i.e. observed mortality will be just as sensitive to expenditure whether or not it is regarded as excess. Therefore, the estimated outcome elasticities can be applied to either observed PBC deaths or excess PBC deaths.

r. Recall from *Chapter 3* and *Appendix 2* that the measure of mortality that is available at PCT level and used to estimate the outcome elasticities is restricted to deaths under 75 years, as are the published estimates of YLL associated with them (see *Life expectancy and years of life lost*). However, to restrict effects only to those under 75 years would imply that there is no excess mortality above 75 years or equivalently that there are no health effects of PBC expenditure above 75 years. Rather than assume no affects of NHS activity in older populations we apply the effects that can be observed to the whole PBC but account for deaths that would otherwise have occurred in our estimate of net YLL in *Years of life lost and accounting for counterfactual deaths*. In many respects whether or not PBC deaths at older ages are as sensitive to changes in expenditure is not critical as any observed deaths that might be averted at older ages are less likely to generate YLGs because they are more likely to have occurred anyway in that year (i.e. are excess so generate zero YLGs anyway). Therefore, they will have very limited impact on cost per life-year or subsequently on cost per QALY (estimates in *Adjusting life-years for quality-of-life* and *Including quality-of-life effects during disease*). For this, and the reasons given in the text, it is the cost per life-year rather than cost per death averted, whether excess or observed, that is of primary interest.

s. What portion of observed deaths are regarded as excess depend on how time is discretised. The data available reports deaths in annual intervals so in this context 'quickly' means within 1 year. If deaths were reported in narrower time intervals then a greater proportion of observed deaths would be regarded as excess and in the limit with continuous time all observed deaths would be excess. Of course, the average YLL associated with them would be smaller and is approximated by the net YLL reported in *Table 12* per observed death (the effects of approximation is likely to be small but unavoidable as it is due to deaths being reported in annual intervals).

t. This is the same as life-years associated with excess deaths, as all observed deaths in this PBC are excess.

u. It would be inappropriate to assign all the change in GMS expenditure to the estimate of cost per life-year based only on the 11 PBCs with outcome elasticities because it would imply that GMS only contributes to these PBCs. Restricting attention to the 11 PBCs with outcome elasticities but allocating part of the change in GMS expenditure to them based on their proportional share of changes in overall expenditure would yield the same cost per life-year as reported in *Table 16,* line (4). It should be noted that including changes in GMS expenditure but not assigning health effects to this PBC is likely to overestimate the threshold because any health effects associated with GMS will not be reflected in the estimated outcome elasticities of other PBCs unless the effects happen to be correlated with changes in expenditure in those PBCs.

v. Estimates of the duration of disease for each U-code are available from the GBD study (see *Table 122* and *Addendum 1: data sources* in *Appendix 3*). This information is also used in *Including quality-of-life effects during disease*.

w. Variation in mortality in the first year of data will only contribute to these estimates if differences are sustained for a minimum of 3 years. Similarly, variation in mortality in the second (third) year will only contribute if it is sustained for a minimum of 2 (1) years. If differences in mortality are similar each

year (contribute equally to the estimates) then estimated effects must have been sustained on average for a minimum of 2 years. As some of the variation in mortality in the first year that is not sustained to the third year will nevertheless be sustained for 1 or 2 years, 2 life-years per death averted represents somewhat less than the minimum, consistent with restricting YLGs to the observed mortality data. Of course, this is the minimum difference in observed rather than unobserved counterfactual excess deaths. Nonetheless, it can be interpreted as an upper bound given the data available and therefore the analysis that has been feasible.

x. See *Addendum 1: data sources* in *Appendix 3* for a description of HSE data and *Appendix 3, Quality of life based on the general population* for the analysis of QoL norms illustrated in *Figure 3*.

y. The only exception is PBC 11 (respiratory) which has a large proportion of deaths occurring above the LE of the PBC population (see *Table 12*).

z. ICD-10 estimates of the QoL score and age were pooled across data sets by considering the number of patients from each data set contributing to estimates, i.e. a weighted average.

aa. The average QoL scores across the ICD-10 codes which contribute to each PBC and the average age and gender of respondents were used to calculate a PBC disease-related decrement based on QoL norms from the general population. This 'PBC decrement' could then be applied to each observed death and the age at which each life-year was gained or lost. In *Including quality-of-life effects during disease* information about the relative share of different types of disease (U-codes) within a PBC and the information about which ICD-10 codes are more likely to contribute to the effects of changes in PBC expenditure are explored.

ab. In principle it would be possible to estimate disease-related disutility by age rather than assume a fixed decrement. HODaR does provide age for each reported QoL score but MEPS only provides average age of respondents in published summaries. However, even with access to 'raw' scores and the age and gender of each, it is very unlikely that there would be sufficient data to estimate age-related decrements in each of the component ICD-10 codes. It would, however, be possible to assume a proportionate rather than fixed decrement by age. As the average age of respondents in the pooled HODaR and MEPS sample tends to be older than the age distribution of the PBC populations (see *Tables 113* and *129* in *Appendix 3*) this would tend to increase the quality-adjusted net YLL and reduce the cost per QALY threshold compared with the fixed decrement applied here.

ac. The QoL score was applied to each observed death considering the age at which each life-year was gained or lost (from ONS) using the 'PBC decrements' from HODaR and MEPS.

ad. The information that is available about disease duration suggests that many types of disease that comprise the PBCs are not chronic and certainly not lifelong (see *Table 122* in *Appendix 3*). In *Including quality-of-life effects during disease* we take account of QoL experienced while alive in the diseased state.

ae. In *Using estimates of the quality-adjusted life-year burden of disease*, measures of QALY burden are used as the basis of estimating the health effects of changes in expenditure. This analysis applies the estimated proportionate effect of changes in expenditure on life-year burden of disease to measures of the total QALY burden. This is equivalent to assigning a proportional adjustment to the QoL with disease to YLGs.

af. Insofar as YLL would not have been lived in full health (see *Adjusting life-years for quality-of-life*), the QoL effects during disease must offset the less than full QoL of the YLL to generate a ratio > 1. Therefore, ratios < 1 are possible even when disease has measurable QoL effects for those experiencing it.

ag. The analysis in *Adjusting life-years for quality-of-life* already implies an R_{death} ratio at PBC level.

ah. Reflecting the QoL norms for the general population in *Figure 3* and the distribution of ages and gender within each U-code (see *Addendum 1: data sources* in *Appendix 3*).

ai. As QoL effects of different disease states are expressed as age-related decrements (see *Figure 4*) we do not require the HODaR and MEPS samples to necessarily be representative of the age distribution of the population at risk in the groups of ICD-10 codes that make up each U-code.

aj. The average QoL scores across the ICD-10 codes which contribute to each U-code (see *Addendum 1: data sources* in *Appendix 3* for how ICD-10 codes map to U-codes) and the average age and gender of respondents from HODaR and MEPS were used to calculate a disease decrement for each U-code, based on QoL norms from the general population. These U-code disease decrements can then be applied to the age and gender distribution of each U-code, based on information from GBD about the prevalence and age distribution of each – using information about the incidence of sequelae associated with them (as described in *Years of life lost and accounting for counterfactual deaths*) and information about the durations of disease (see *Appendix 3, Table 122*).

ak. For example, the evidence about QoL from HODaR and MEPS suggests that the impact of U037 on QoL is greater than indicated by DALY disability weights. The QoL effects of U141, although still very significant, are lower than indicated by DALY disability weights.

al. Information about the size, and age and gender distribution is only available at U-code level. Therefore U-code ratios are applied to all the ICD-10 codes that contribute to a particular U-code. Note that, unlike ICD-10 codes, U-codes do not map directly to PBCs so some ICD-10 codes in different PBCs may belong to the same U-code and therefore have the same U-code ratio. Some ICD-10 codes are not included in the U-code classification of disease. Most of these are procedural codes where we do not assign life-year and QALY effects anyway (any health effects would be evident in other ICD-10 codes), so it was not necessary to impute ratios for them (84 out of 1562). Of the others, most were associated with PBC 16 with a zero outcome elasticity so did not require imputation either (186 out of 1562). Imputation based on the median ratio across the ICD-10 codes within the PBC was required for the remaining (482 out of 1562). Eighty-eight of these cannot be mapped into U-codes. The remaining 394 were associated with U-codes where the ratio was undefined because the denominator (YLL) was zero. In both these cases, values were imputed based on the median ratio across the ICD-10 codes within the PBC. As the distribution of ratios within a PBC tend to be highly positively skewed, imputation based on the median is likely to be conservative with respect to health effects and especially in the latter case where mortality effects appear to be a much less important aspect of the disease.

am. It is important to note that it would be inappropriate to calculate an average of the ratios within a PBC and then apply this 'average ratio' to life-year effects at PBC level, rather than calculate QALY effects at ICD-10 level by applying the relevant ratio. The results, however, can be presented as an implied PBC ratio (i.e. a ratio of averages) (see *Table 145* in *Appendix 3*).

an. Unfortunately, total PBC costs are not available at ICD-10 level across PCTs so could not be used for this purpose. Costs from HES data are only a component of total PBC costs (41% of total PBC costs for the 11 PBCs where mortality effects can be estimated) and contribute less to the variability in PBC costs across PCTs (HES contribute only 23% of the variability for the 11 PBCs where mortality effect can be estimated).

ao. It should be noted that the implied QALY ratio of 1.52 for the 11 PBCs with outcome elasticities is a ratio of QALYs to unadjusted YLL. The proportion of total QALY effects due to premature deaths for the same PBCs (50% in *Table 26*) also implies a ratio – equal to 2. However, this is a ratio of total QALY effects to quality-adjusted YLL. The difference between these two ratios is the denominator (i.e. quality-adjusted YLL are lower than unadjusted YLL).

ap. In *Adjusting life-years for quality-of-life* each YLG could be assumed to be lived in full health, i.e. lived in a QoL that reflects age and gender norms of the general population or lived in a QoL that reflects the original disease state. Applying an estimated proportionate effect on the life-year burden of disease to measures of QALY burden of disease implies a proportionate improvement in the QoL with disease applied to any life-year effects. Therefore, basing estimates on measures of

QALY burden provides a more conservative estimate of the QALY effects of changes in mortality than the best estimate reported in *Adjusting life-years for quality-of-life*, which was based on QoL norms.

aq. Previously in *Chapter 3* and in *From mortality to life-years*, *Adjusting life-years for quality-of-life* and *Using ratios of quality-adjusted life-years to years of life lost*, expenditure elasticities were only estimated for PBC 23 and the 11 PBCs where outcome elasticities could be estimated, with the remaining change in total spend assigned to the other 11 PBCs. As a consequence, proportionally more of the share of a change in total spend was allocated to these other PBCs in previous sections [see column (3) of *Table 108* in *Appendix 3*].

ar. Of course it would be possible to solve for a lower outcome elasticity that could be applied to total burden which would return the required estimate of total QALY effects restricted to 1 year (see *From mortality to life-years* in *Appendix 3*).

as. As long as estimates of the QoL decrement of disease from HODaR and MEPS are representative of average effects across those earlier (incident) and later (prevalent) in their disease duration, an assumption of constant QoL decrement with respect to disease duration is not required.

at. There are a number of reasons for potential inconsistencies: (i) GBD is based on earlier years of mortality data; (ii) the imprecision of mapping from U-codes to PBC via ICD-10 codes; and (iii) the YLL reported in GBD are calculated in the same way as published NHS IC estimates (see *Life expectancy and years of life lost* and *Years of life lost and accounting for counterfactual deaths*) and will tend to overestimate the net YLL (see *Table 146* in *Appendix 3*). The YLL by U-code, reported in GBD, that are mapped to ICD-10 codes are adjusted by these proportionate differences to ensure that the YLL associated with all contributing ICD-10 codes are consistent with (do not overestimate) the net YLL for the PBC as a whole. However, due to the earlier years of data and imprecision in mapping from U-codes to ICD-10 codes there might also be some inconsistency in estimates of the total incidence of disease for a PBC. Insofar as disease-related mortality risk is stable, the same number of deaths should be observed in GBD and ONS data for the same at risk population. The PBC deaths recorded in GBD and those observed in ONS data (see *Table 146* in *Appendix 3*) are similar but nonetheless the proportionate difference is used to adjust the scale of QoL burden while alive based on GBD information (equivalent to adjusting estimates of incidence). Notable exceptions are PBC 1 and PBC 18 + 19 where the discrepancies are due to imperfect mapping from U-codes to PBC via ICD-10 codes.

au. HES costs are a much smaller proportion of total PBC expenditure for the 11 PBCs where mortality effects could not be estimated (HES costs account for < 15% of total PBC expenditure) and account for very little of the variability in PBC costs across PCTs (the contribution that variance in HES costs makes to variance in PBC expenditure in this group of PBCs is < 8%). Therefore allocating PBC level effects to ICD-10 codes based on contribution to variance in HES costs is less appropriate when information about QALY burden in this group of PBCs is used to inform the estimate of the overall threshold.

av. See note au and *Table 154* in *Appendix 3*.

aw. Note that this is the ratio of total change in health to total change in expenditure across these PBCs (rather than an average ratio), and the contribution that each of these PBCs make to these total effects on health and expenditure depends on the estimated expenditure as well as outcome elasticities.

ax. Applying the absolute health effect of expenditure from the 11 PBCs with outcome elasticities implies different (higher) proportionate effects in the other PBCs.

ay. The QALY burdens per incident patient are reported in this *Table 147* for each PBC, including the median and range across the contributing ICD-10 codes. However, these values should not be over interpreted as the 'average' QALY burden for the PBC depends on how PBC effects are allocated to ICD-10 codes and the 'average' burden for groups of PBCs depends on how a change in overall

expenditure is shared between them (i.e. the expenditure elasticities estimated for each PBC in *Chapter 3* and *Appendix 2*).

az. See *Addendum 3: characterisation of the investment and disinvestment decisions in mental health – depression and schizophrenia* in *Appendix 3* for an examination of the value of investment and disinvestments that may have been available in PBC 5 (mental health disorders), which accounts for much of the change in overall expenditure.

aaa. The exception is PBC 18 + 19. The reason is that there are significant adjustments made based on differences in observed and recorded mortality (to adjust for differences in classification when mapping from U-codes to PBCs via ICD-10 codes) as well as differences in YLL due to the GBD method of calculation (see *Table 146* in *Appendix 3*).

aab. The implied QALY ratios across these 11 PBCs range from 0.70 in PBC 2 (cancer) to 14.86 in PBC 7 (neurological).

aac. The cost per life-year threshold in *Table 16* can be interpreted as cost per QALY thresholds conditional on the assumption that all life-years are lived in full health and the QoL with disease is zero (equivalent to death).

aad. Note that the proportionate differences between the estimates in *Table 29*, column (3) and columns (1) and (2) are greater in lines (1) and (2), reflecting the additional health effects from considering the likely impact of changes in expenditure on QoL during disease. These differences are less marked in line (3) because the effects in those PBCs where an outcome elasticity can be estimated are extrapolated to the other PBCs using proportionate effect on QALY burden and measures of QALY burden in these other PBCs (see the discussion in *Using estimates of the quality-adjusted life-year burden of disease* for more details).

aae. It would be inappropriate to assign all the change in GMS expenditure to the estimate of cost per QALY based only on the 11 PBCs with outcome elasticities because it would imply that GMS only contributes to these PBCs. Restricting attention to the 11 PBCs with outcome elasticities but allocating part of the change in GMS expenditure to them based on their proportional share of changes in overall expenditure would yield a slightly higher cost per QALY than reported in *Table 29*, line (2). It should be noted that including changes in GMS expenditure but not assigning health effects to this PBC is likely to overestimate the threshold because any health effects associated with GMS (or PBC 22, see notes m and u) will not be reflected in the estimated outcome elasticities of other PBCs unless the effects happen to be correlated with changes in expenditure in those PBCs.

Chapter 5

a. The cost per life-year threshold in *Table 30*, column (1) can be interpreted as cost per QALY threshold conditional on the assumption that all YLGs or lost are lived in full health but the QoL with disease is zero (equivalent to death).

b. The cost per life-year adjusted for QoL in *Table 30*, column (2) can be interpreted as cost per QALY threshold conditional on the assumption that the QoL with disease is zero (equivalent to death); effectively ignoring any effects on those who survive with disease.

c. It would be inappropriate to assign all the change in GMS expenditure to the estimate of cost per QALY based only on the 11 PBCs with outcome elasticities because it would imply that GMS only contributes to these PBCs. Restricting attention to the 11 PBCs with outcome elasticities but allocating part of the change in GMS expenditure to them based on their proportional share of changes in overall expenditure would yield a slightly higher cost per QALY than reported in *Table 30*, line (2). It should be noted that including changes in GMS expenditure but not assigning

health effects to this PBC is likely to overestimate the threshold because any health effects associated with GMS or PBC 22 social care (see *Chapter 4*, note o), will not be reflected in the estimated outcome elasticities of other PBCs unless the effects happen to be correlated with changes in expenditure in those PBCs.

d. The effects of discounting are modest because (i) the health effects of a change in expenditure are restricted to 1 year (where no discounting is necessary); (ii) most of the total QALY effect occurs in that year; (iii) it is only some of the life-year effects (adjusted for quality) of a change in mortality in that year that occur in future years that need to be discounted; and (iv) these need to be discounted only over 4.6 years on average (see *Tables 191* and *192* in *Appendix 3* for discounted values).

e. Which is determined by the estimated expenditure elasticities (the proportionate change in PBC expenditure due to a change in overall expenditure) and total PBC expenditure (see *Chapter 3* and *Analysis of programme budgeting expenditure for 2008/9 and mortality data for 2008/9/10* in *Appendix 2*).

f. Which are determined by the outcome elasticities (the proportionate effects on mortality and YLL of a proportionate change in PBC expenditure, see *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* for details of how these estimates can be applied to measures of QALY burden in all PBCs).

g. See *Chapter 4, Including quality-of-life effects during disease* for how PBC level effects can be allocated to the contributing ICD-10 codes and how measures of QALY burden for each ICD-10 code can be established.

h. Within PBC 11, chronic lower respiratory diseases (J40–J47) account for 85% of the QALY effects of a change in PBC expenditure; lung diseases due to external agents (J60–J70), 4%; other diseases of the upper respiratory tract (J30–J39), 4%; other respiratory diseases principally affecting the interstitium (J80–J84), 1%; and other diseases of pleura (J90–J94), 1%. The other ICD-10 codes each contribute less, but together account for 4% of the health effects of a change in PBC 11 expenditure.

i. Within PBC 10, ischaemic heart diseases (I20–I25) accounts for 55% of the QALY effects of a change in PBC expenditure; cerebrovascular diseases (I60–I69), 21%; other forms of heart disease (I30–I52), 7%; congenital malformations and deformations of the circulatory system (Q20–Q28), 3%; and diseases of veins, lymphatic vessels and lymph nodes, not elsewhere classified (I80–I89), 3%. The other ICD-10 codes each contribute less but together account for 8% of the health effects of a change in PBC 10 expenditure.

j. Within PBC 7, episodic and paroxysmal disorders (G40–G47) account for 73% of the QALY effects of a change in PBC expenditure; extrapyramidal and movement disorders (G20–G26), 8%; other degenerative diseases of the nervous system (G30–G32), 5%; other disorders of the nervous system (G90–G99), 3%; and nerve, nerve root and plexus disorders (G50–G59), 2%. The other ICD-10 codes each contribute less but together account for 9% of the health effects of a change in PBC 7 expenditure.

k. HES costs only account for 16.8% of total costs in PBC 5 and only explain 5.9% of the variance in PBC costs across PCTs (see *Chapter 4*, notes an, au and *Chapter 5*, note ai), therefore it seems unlikely that a large proportion of investment and disinvestment in this PBC has been associated with these ICD-10 codes.

l. Although the published evidence suggests that investment and disinvestment opportunities in this PBC tend to be much more valuable than the implied cost per QALY, we have little information on the particular investments and disinvestments that were actually made by PCTs. The review of local data sources (see *Appendix 3*, *Addendum 2: the role of data on local NHS decisions*) revealed very little routinely collected information about specific investments and disinvestments beyond more aggregate measures of spending. In common with other PBCs, there will inevitably be inefficient,

ineffective or even iatrogenic practice (e.g. due to poor diagnosis and inappropriate prescribing). Insofar as these types of activities are sensitive to changes in PBC expenditure this will tend to increase the cost per QALY associated with changes in expenditure in this PBC. Whether or not both the extent of these inefficiencies and their sensitivity to changes in expenditure are sufficient to increase the cost per QALY above £18,744 is unclear, although it seems unlikely. Note that the effects of the scale and sensitivity to expenditure of inefficient or even harmful practice in the other PBCs where outcome equations could be specified are already captured in the estimated outcome elasticities.

m. In principle, at least, with sufficient panel data which would allow a more complex lag structure and simultaneous estimation of expenditure and outcome elasticities across all PBCs, it might be possible to isolate the short run effects of a change in expenditure in one PBC across all the others. In the absence of such data and so long as adjustments are expected take place quickly relative to the time horizon of the effects of the new technology on NHS cost and outcomes (i.e. marginal NHS resources can be reallocated in the medium term), using the overall cost per QALY threshold for technologies relevant to any PBC is reasonable and more so than other alternative assumptions that might be made.

n. The health effects of a change in expenditure in a 'contributory' PBC will not be reflected in the estimated health effects of change in expenditure in the 'recipient' PBCs unless they happen to be correlated with changes in expenditure in the 'recipient' PBCs, i.e. all changes in expenditure are assigned to PBCs but all the health effects may not be. This suggests that the health effects are likely to be underestimated and the overall threshold underestimated.

o. The quite general theoretical framework in *Chapter 3* assumes that PCTs maximise some unspecified welfare function where health (not necessarily QALYs) is one of its arguments (see *Chapter 3, Modelling framework*). The type of econometric analysis conducted would remain the same irrespective of the measure of health or weights that might be place on different types of health gained or lost. The assumption required is that mortality is related to the 'health' argument, however, 'health' might be specified. We make no comment on whether or not QALY maximisation ought to be the objective of PCTs, nor is that required to estimate a threshold for NICE which is currently based on cost per (unweighted) QALY.

p. A form of value of information analysis could be applied to these estimates in subsequent research, ideally capturing some of the other sources of uncertainty. Such analysis has firm foundations in statistical decision theory and has been applied to health-care decisions. More recently it has been applied to the decisions faced by NICE when considering whether or not there is sufficient evidence to support the approval of a new technology.

q. The Monte Carlo simulation is in essence Bayesian, where the standard errors from the frequentist econometric analysis are used to assign normal prior distributions with means equal to the point estimates and a standard deviation equal to the estimated standard errors. This is equivalent to a fully Bayesian analysis with initially uninformative priors which are updated through the analysis of expenditure and mortality data.

r. Note that the mean of the simulated values is not the mean of the sampled ratios but the ratio of the mean sampled values for the numerator and denominator. Deterministic and simulated values are the same for 2006, 2007 and 2008 expenditure data (other than negligible Monte Carlo error from 1000 samples). Also note that in constructing the cumulative probability density function in *Figure 5* and the histograms of values in *Appendix 3* it is important to identify whether sampled negative values favour a low value for the threshold or an unbounded one (there were no negative values sampled in the simulation of values for all 23 PBCs).

s. Positive correlation suggests that a high spend elasticity will be associated with a high outcome elasticity (i.e. less negative, implying a smaller heath effect of a change in expenditure) resulting in a higher estimate of the threshold. It also suggests that when spend elasticity is low, outcome elasticity will also tend to be lower (i.e. more negative, implying a larger health effect of a change in expenditure) resulting in a lower estimate of the threshold. Although realisations of spend elasticities higher and lower than the mean estimate are equally likely, higher spend elasticities provide a greater 'weight' associated with higher estimates of the threshold (where outcome elasticity is also high) when calculating the mean threshold. For these reasons a positive correlation will tend to increase the mean estimate of the threshold.

t. Only a negative skew in the distribution of the threshold would tend to offset the implications of the non-linear relationship between NHB and the value of the threshold. However, in this case the mean estimate is very similar but slightly greater than median values (see *Using ratios of quality-adjusted life-years to years of life lost* in *Appendix 3*) indicating a small positive skew, which reinforces the implication that the policy threshold should be below the expected or mean value.

u. Rather than solve for this type of 'certainty equivalent', a probabilistic analysis of the cost-effectiveness of a technology which integrated the uncertainty associated with the cost per QALY threshold as well, would take account of these issues (i.e. the technology would be cost-effective if it offered the highest expected net benefit when averaged over all Monte Carlo simulations, including sampling from the distribution of the cost per QALY threshold).

v. Although health benefits can be expressed in terms of consumption (in money) using some consumption value of the health effects (WTP), NHS costs must be first converted into health forgone, using an uncertain estimate of the threshold, before these are also expressed in consumption (money terms) using the same consumption value of health, i.e. the non-linear effect of the threshold remains unavoidable. Failure to account for the threshold and the implications of its uncertainty would only be reasonable in a heath-care system where expenditure was not constrained and/or all costs fell on private consumption.

w. There are of course other unquantified sources of structural uncertainty in any statistical model. In this case the underlying model is based on a production function for health consistent with Cobb–Douglas, which has firm theoretical foundations and has been widely used in health and elsewhere. Although it might be possible to test more flexible function forms (also founded in economic theory) to quantify this other source of structural uncertainty, there are no reasons to believe that more flexible functional forms would necessarily increase or reduce the estimates of outcome elasticities.

x. What can be estimated is the health effect over the observed variation in expenditure. This will also be the 'true' marginal effect (tangency at a budget of B1) if health returns to expenditure diminish at a constant rate (the second derivative is constant) as illustrated in *Figure 7*. As nothing is 'truly' marginal the important question is how the threshold changes with the sign and scale of the non-marginal budget impact associated with approval of a new technology.

y. Due to the diminishing marginal returns illustrated in *Figure 8* (see *Impact of investment, disinvestment and non-marginal effects* for further explanation).

z. 2008 expenditure expressed in 2007 NHS prices based on 3.9% NHS inflation from the HCHS index – see *Adjusting the cost of life-year estimates to constant prices* in *Appendix 2*.

aa. See *Tables 157* and *184* in *Appendix 3* for a summary of outcome and expenditure elasticities and total expenditure by PBC in 2007 and 2008. Also see *Table 180* in *Appendix 3* with *Table 31* for an indication of these net effects on the share of health effects and changes in expenditure.

ab. If the growth rate in the nominal threshold between 2007 and 2008 was applied, the current 2012 threshold would be expected to be £10,536.

ac. All relevant documentation is available at NICE.[108,109]

ad. Although there was insufficient mortality at PCT level to estimate outcome elasticities for the other PBCs, the measure of QALY burden in some of these PBCs does include some mortality (based on ONS data). Therefore, applying a proportionate effect to measures of QALY burden of will include some mortality and life-year effects although they represent only a small proportion of the total QALY effects.

ae. The differences in contribution to deaths compared with life-years reflects the distribution of age at death and the age and gender distribution of the population at risk in the ICD-10 codes that contribute to each PBC (see *Chapter 4*, *From mortality to life-years* and *Addendum 1: data sources* in *Appendix 3*).

af. Information about the age, gender and the incidence of sequelae associated with different diseases within a PBC are only available for U-codes which can be mapped to groups of three-digit ICD-10 codes. Also allocating PBC level effects to ICD-10 codes was based on the proportion of the total PBC population within each contributing ICD-10 codes because PBC costs are not available at ICD-10 code level across PCTs. Although costs from HES data are available at ICD-10 code level they are only a small component of total PBC costs and contribute very little to the variability in PBC costs across PCTs especially in those PBCs where mortality effects could not be estimated (also see *Chapter 4*, notes ap and av, and *Addendum 1: data sources* in *Appendix 3*).

ag. This is implicit in the estimates of outcome elasticities presented in *Chapter 3*. Although 3 years of mortality data are used in the analysis of each year of expenditure, these are averaged to an annual value prior to estimating outcome elasticities, so the estimated outcome elasticities represent the proportionate effect on mortality in 1 year due to a proportionate change in expenditure. This is likely to underestimate effects on mortality as expenditure that reduces mortality risk (or reduces the QALY burden of disease) for an individual in 1 year may well also reduce their risk (reduce QALY burden) over subsequent years; possibly over the whole of their remaining disease duration. Expenditure may also prevent disease in future patient populations. Therefore, total health effects will be underestimated and the cost per life-year or QALY threshold will be overestimated.

ah. The YLG associated with each death averted are based on what would have been their LE taking account of their age and gender (using life tables for the general population).

ai. It should be recognised that the purpose is to inform an assessment of the threshold for decisions that have not yet been made (i.e. prediction for decisions not yet made rather than a description of the past). Therefore, irrespective of the availability of evidence or the sophistication of analytical methods, the need for assumptions or scientific value judgements can never be avoided but only better informed.

aj. The nature of prediction to inform decisions, combined with the reality of a forever unobserved counterfactual makes judgement unavoidable – see note ai.

ak. For example, a more structural approach of estimating an outcome equation jointly with an expenditure equation, both with appropriately specified lag structures and controlling for unobserved PCT effects might be possible, although changes to PCT boundaries, recording of PBC data and the recent formation of Clinical Commissioning Groups (CCGs) makes the time series problematic.

al. The health effects of previous changes in expenditure in $t-n$ will not be reflected in estimates of the health effects of changes in expenditure in t unless they happen to be correlated with changes in expenditure in t. Therefore, excluding a longer lag structure for the health effects of changes in expenditure in $t-n, \ldots t, \ldots, t+n$ is likely to underestimate the effects of changes in expenditure in t.

am. These effects will be picked up in the cross-sectional variation, at least partially, so long as there is some variation in the health effects achieved and scale of simultaneous investment or disinvestment across PCTs.

an. This would be particularly interesting when reconsidering the subgroup analysis in *Impact of investment, disinvestment and non-marginal effects* with panel data.

ao. We have taken account of competing risks or counterfactual deaths (which might appear in any of the PBCs in our calculation of net YLL – see *Chapter 4, Years of life lost and accounting for counterfactual deaths*). The health effects of a change in expenditure in 'contributory' PBCs will not be reflected in the estimated health effects of change in expenditure in the 'recipient' PBCs unless they happen to be correlated with changes in expenditure in the 'recipient' PBCs, i.e. all changes in expenditure are assigned to PBCs but all the health effects may not be. This suggests that the health effects are likely to be underestimated and the overall threshold underestimated (see *Which programme budget categories matter most?* and note p).

ap. The vast majority of hip and knee replacements are for osteoarthritis which is included in PBC 15.

aq. These data have only been collated centrally since April 2012 despite IAPT sites collecting these data at individual patient encounters for many years. In April 2012, the IAPT data standard was approved by the NHS Information Standards Board as a nationally mandated data standard. Data is now collected centrally on a monthly basis from over 200 service locations. The first report on the quality of IAPT data was published in November 2012 but the quarterly IAPT data reports, which were scheduled to be released at the same time have not been made available. Although there is a commitment to make the data set publicly available, the timing and details of what will be available (summaries or patient-level data and whether it will include the waves of data collected since 2006) and who might have access (commissioners, service providers or independent researchers) remains unclear (see www.iapt.nhs.uk and www.hscic.gov.uk/iapt).

ar. Similar difficulties will arise, however, when translating the observed impact of a therapy on QoL, before and immediately after the intervention, into longer-term effects.

Appendix 1

This is the aim of a value-based pricing approach previously considered by the Department of Health.[2]

a. In fact, the 2004 NICE Methods Guide[5] noted that 'the threshold will change over time as the budget for healthcare changes' (p. 33). However, there is no clear reference to this change in the 2008 Methods Guide.[3]

Appendix 2

a. This study builds on previous work that was undertaken as part of the Quest for Quality and Improved Performance, a 5-year initiative of the Health Foundation.

b. Strictly speaking, these local health authorities are PCOs but the vast majority of these are 'trusts' and we retain this terminology throughout.

c. In April 2010 two PCTs [East and North Hertfordshire (5P3) and West Hertfordshire (5P4)] merged to form a single organisation [Hertfordshire PCT (5QV)] so that, since this date, there have been 151 PCTs. At the same time Blackburn and Darwen PCT (5CC) became Blackburn and Darwen Teaching Care Trust Plus (TAP). In April 2011 Solihull Care Trust (TAM) became a PCT (5QW).

d. Some commentators have suggested that some of the within programme variation in expenditure observed across PCTs reflects different accounting conventions or unknown local factors. One way of reducing the impact of such unobserved heterogeneity is to construct a longitudinal data set with expenditure and mortality for each PCT for several years. With the availability of several years of data for both expenditure and mortality, we wanted to estimate a panel data model. However, most of the instruments employed here are based on the 2001 Census and thus estimation of a panel model will not be possible until these too become time variant; this should occur later this year with release of the 2011 Census data at PCT level. The same difficulty arises with the estimation of an incremental model.

e. This figure ignores intracategory changes (e.g. where an ICD-10 code is reallocated from category 1A to 1B) and only counts cross-category changes (e.g. where the code is switched from category 1 to category 2).

f. This expert review also led to the introduction of 40 additional subcategories including 10 subcategories for the cancer and tumour programme.

g. Expenditure on, for example, community care, A&E, ambulance services and outpatients can be difficult to attribute a particular PBC. Critical care, rehabilitation and specialised commissioning across care settings will also be difficult to attribute to a particular programme.

h. This cost adjustment reflects the fact that health economy input prices vary considerably across the country and, for some inputs, are up to 40% higher in London and the south east of England than elsewhere. We have used a weighted average of the three MFFs for HCHS, for prescribing, and for GMS/PMS to adjust the raw expenditure figures in *Table 2* for local input prices.[74]

i. This needs adjustment incorporates the AREA resource allocation formula for HCHS.[76]

j. The Association of Chartered Certified Accountants (ACCA)/Audit Commission [Association of Chartered Certified Accountants (ACCA)/Audit Commission. Costing Care Pathways: Understanding the Cost of the Diabetes Care Pathway. London: ACCA/Audit Commission; 2011] looked at the reliability of the PB data for the diabetes subgroup within the endocrine and metabolic problems category. The ACCA/Audit Commission noted that PB data includes inpatient and prescribing expenditure, which are thought to be relatively reliably allocated to PBCs and to be consistently costed across PCTs, and outpatient and community service expenditure, which are thought to be less reliably allocated to PBCs and to be less consistently costed across PCTs. The ACCA/Audit Commission compared the variation in expenditure for inpatient and prescribing expenditure with that for total programme budget expenditure and found that the latter was far greater than the former. However, the interpretation of this result is not straightforward; as the ACCA/Audit Commission noted, it is difficult to know whether differences in programme budget spend are attributable to variation in service provision and efficiency, or simply to different approaches to cost allocation.

k. One exception to this is the mortality rate for the trauma and injuries programme where initially only SMRs were available.

l. The NHS IC reports mortality rates using deaths pooled over a 3-year period because the relatively small number of annual deaths in some disease categories might lead to large year-on-year fluctuations in death rates at PCT level.

m. However, we do experiment with replacing and supplementing this all service measure of need with more programme-specific measures where these are available (e.g. using the diabetes and epilepsy prevalence rates).

n. Although need is a function of mortality/morbidity in the resource allocation formula, the relationship is not sufficiently strong enough for us to be concerned about the endogeneity of the need in any individual care programme.

o. When estimating expenditure equations using PB data for 2005/6 for cancer and circulatory disease we persevere (for continuity with previous studies) with the use of the circulatory disease SYLLR as the proxy for other programme need in the cancer programme, and we use the cancer SYLLR as the proxy for other programme need in the circulatory disease programme (see Martin *et al.*[60,63]).

p. The IV procedure involves the estimation of the second-stage expenditure equation as specified in *Equation 12* and the estimation of a first-stage expenditure equation associated with *Equation 13*. The same variable might have different coefficients in these two equations because the equations will have different sets of covariates.

q. For the case of a single endogenous regressor and three excluded instruments, Stock and Yogo[80] critical values are as follows in terms of the bias of 2SLS relative to bias of OLS: relative bias 5%, critical value = 13.9; relative bias 10%, critical value = 9.08; relative bias 20%, critical value = 6.46; relative bias 30%, critical value = 5.39.

r. The OLS version of Ramsey's[81] reset test was invoked using Stata's -ovtest- command, and the IV equivalent was invoked using -ivreset-.

s. As all PCTs face the same prescribing costs, the prescribing MFF is 1 for all PCTs.

t. The 'big four PBCs' are the cancer, circulatory disease, respiratory problems and gastrointestinal problems. They are 'big' programmes in terms of the number of deaths associated with each programme.

u. The programme-specific cost per life and life-year estimates presented here will underestimate the true programme-specific costs because not all PCT expenditure can be allocated to a specific programme (e.g. all GMS expenditure is allocated to PBC 23 rather than being split between cancer, circulatory disease, respiratory problems, etc.). However, this more generic expenditure *is* incorporated into the calculation of the cost of a life-year when this calculation is undertaken across all programmes.

v. These are the 'big four PBCs' in terms of the number of lives (or life-years) lost.

w. The cost of a life-year for a group of PBCs is calculated by dividing (a) the sum of the change in spend on the component PBCs by (b) the sum of the change in the number of lives/life-years lost for the component PBCs.

x. We are grateful to Steve Morris for this suggestion.

y. Instead of estimating programme-specific models we also tried estimating an outcome model using the all-cause mortality rate and expenditure across all programmes combined but this was not successful (again, counterintuitive signs were obtained on some variables). We also investigated the possibility of using an overall measure of health derived from the HSE. Apart from sample size issues at PCT level (4645 adults in England were interviewed for the 2009 survey), such surveys by definition only provide information about the health status of the living population and reveal nothing about the level of mortality.

z. The cost of a life-year for those 13 programmes where there is no health gain is, of course, undefined.

aa. Note that implied need = unified weighted population/(CARAN MFF × raw population).

ab. Ideally, the test *F*-statistic should be ≥ 10.

ac. Clearly, some expenditure in year t will have an effect on mortality beyond $t + 2$ but we have no mortality data that would allow us to include this in our modelling work. We must assume that, for expenditure that affects mortality beyond $t + 2$, PCTs have reached some sort of equilibrium position in terms of their expenditure choices and the outcomes secured.[108,109]

ad. When re-estimating the all PCT model for 'high spenders' and then for 'low spenders', no attempt was made to adjust the estimating equation for any implied model misspecifiaction.

ae. The cost of a life-year estimates presented in *Table 74* are not adjusted for the mismatch in the ICD-10 coverage of the expenditure and mortality data because such an adjustment would not affect our conclusions.

af. See column (1) of *Table 65* for the estimated IV cancer outcome model.

ag. We used a symmetrical distribution about zero because we have no priors about the signs of the coefficients on the instruments. The use of a uniform distribution is arbitrary but of no significance.

ah. The outcome model for circulatory disease reported in *Table 65* (using PB expenditure for 2006/7 and mortality data for 2006/7/8) contains four instruments. The application of the sensitivity analysis described in this section is considerably easier to implement if only two instruments are present and re-estimation of the outcome model for circulatory disease without the two least significant instruments generates very similar results to those obtained with all four instruments (e.g. the coefficient on expenditure declines marginally from –1.434 to –1.427). Therefore, the sensitivity analysis reported here uses the outcome model containing only two instruments.

ai. The Kleibergen–Paap *F*-statistic is very close to the target value of 10 for both the genitourinary and infectious diseases outcome models.

aj. Expenditure on, for example, community care, A&E, ambulance services and outpatients can be difficult to attribute to a particular PBC. Critical care, rehabilitation and specialised commissioning across care settings will also be difficult to attribute to a particular programme.

ak. With the index for 1987/8 set equal to 100, then 2005/6 = 240.9, 2006/7 = 249.8, 2007/8 = 257.0, and 2008/9 = 267.0.[87]

Appendix 3

a. The calculated mid-points are as follows:

Age range (years)	< 1	1–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44
Mid-point	0.5	3.0	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5
Age range (years)	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90+
Mid-point	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5

b. The YLL available from NHS IC represented all deaths from maternity and all deaths under 28 days across PBCs. The coverage factor (0.679) adjusts this YLL to represent maternity and all deaths < 1 year across PBCs. The calculation is described in *Appendix 2*, *Table 37* footnotes.

c. Figures for England, from ONS.[152]

d. Note that the outcome elasticities are based on PBC mortality that is sensitive to changes in expenditure (i.e. is avoidable) at the margin so no assumptions about how much of the PBC mortality is avoidable is required.

e. Although this research was not funded to purchase access to GPRD data we were able to examine a sample of it which comprised of 22,313,086 rows/patient–ICD-10 events (three digit) representing 4,229,910 patients with data on new diagnosis of diseases observed between 1 January 2006 and

24 June 2011 (see *Addendum 1: data sources*). Although GPRD data could, in principle, provide this type of information the difficulties of reliability, face validity and interpretation of the sample data in the form available to us meant that it was not directly useful.

f. We are aware that the 2000–2 WHO GBD study and the update which was published in 2008 using 2004 data has itself recently been updated. However, the report and tools were not publically available at the time this research was conducted.

g. Throughout the analyses in this appendix, mortality, life-years and QALY were not assigned to procedural ICD-10 codes (i.e. those in ICD-10 chapter Z, Factors influencing health status and contact with health services). Health effects from increased spending on these ICD-10 codes would either be non-existent or would be evident in other ICD-10 codes related to the procedure. This means that no health effects are associated with PBC 22 social care (which only includes procedural ICD-10 codes), although changes in expenditure on PBC 22 are included. This is likely to overestimate the threshold because any health effects associated with PBC 22 will not be reflected in the estimated outcome elasticities of other PBCs unless the effects happen to be correlated with changes in expenditure in those other PBCs.

h. This is the same as life-years associated with excess deaths, as all observed deaths in this PBC are excess.

i. It should be noted that including changes in GMS expenditure but not assigning health effects to this PBC is likely to overestimate the threshold because any health effects associated with GMS will not be reflected in the estimated outcome elasticities of other PBCs unless the effects happen to be correlated with changes in expenditure in those PBCs.

j. This information is also used in *Including quality-of-life effects during disease*.

k. As some of the variation in mortality in the first year that is not sustained to the third year will nevertheless be sustained for 1 or 2 years, 2 life-years per death averted represents somewhat less than the minimum, consistent with restricting YLGs to the observed mortality data.

l. The table below reports the cost per QALY threshold using a relative weight based on the size of the ICD-10 code population to allocate health effects:

	Cost per QALY threshold (£)		
	(1) DALY ratios	(2) Adjusted DALY ratios	(3) QALY ratios (HODaR and MEPS)
All big four programmes	4400	5100	2340
11 PBCs (with mortality)	8066	9267	4212
All 23 PBCs	9117	10,474	4760

m. In *Chapter 4*, *Adjusting life-years for quality-of-life* each life-year gained could be assumed to be lived in full health, lived in a QoL that reflects age and gender norms of the general population or lived in a QoL that reflects the original disease state. Applying an estimated proportionate effect on the life-year burden of disease to measures of QALY burden of disease implies a proportionate improvement in the QoL with disease applied to any life-year effects. Therefore, basing estimates on measures of QALY burden provides are more conservative estimate of the QALY effects of changes in mortality than the best estimate reported in *Chapter 4*, *Adjusting life-years for quality-of-life*, which was based on QoL norms.

n. HES costs are a much smaller proportion of total PBC expenditure for the 11 PBCs where mortality effects could not be estimated (HES costs account for < 15% of total PBC expenditure) and account for very little of the variability in PBC costs across PCTs (the contribution that variance in HES costs makes to variance in PBC expenditure in this group of PBCs is < 8%). Therefore, allocating PBC level effects to ICD-10 codes based on contribution to variance in HES costs is less appropriate when

information about QALY burden in this group of PBCs is used to inform the estimate of the overall threshold.

o. Note that this is the ratio of total change in health to total change in expenditure across these PBCs (rather than an average ratio) and the contribution that each of these PBCs make to these total effects on health and expenditure depends on the estimated expenditure as well as the outcome elasticities.

p. Applying the absolute health effect of expenditure from the 11 PBCs with outcome elasticities implies different (higher) proportionate effects in the other PBCs.

q. Note that the proportionate difference between the estimates in *Table 153* column (3) and columns (1) and (2) are greater in lines (1) and (2), reflecting the additional health effects from considering the likely impact of changes in expenditure on QoL during disease. These differences are less marked in line (3) because the effects in those PBCs where an outcome elasticity can be estimated are extrapolated to the other PBCs using proportionate effect on QALY burden and measures of QALY burden in these other PBCs.

r. It would be inappropriate to assign all the change in GMS expenditure to the estimate of cost per QALY based only on the 11 PBCs with outcome elasticities as it would imply that GMS only contributes to these PBCs. Restricting attention to the 11 PBCs with outcome elasticities but allocating part of the change in GMS expenditure to them based on their proportional share of changes in overall expenditure would yield a slightly higher cost per QALY than reported in *Table 153*, line (2). It should be noted that including changes in GMS expenditure but not assigning health effects to this PBC is likely to overestimate the threshold because any health effects associated with GMS (or PBC 22 see *Chapter 4*, notes m and u) will not be reflected in the estimated outcome elasticities of other PBCs unless the effects happen to be correlated with changes in expenditure in those PBCs.

s. Which are determined by the estimated expenditure elasticities (the proportionate change in PBC expenditure due to a change in overall expenditure) and total PBC expenditure (see *Chapter 3* and *Analysis of programme budgeting expenditure for 2008/9 and mortality data for 2008/9/10* in *Appendix 2*).

t. Which are determined by the outcome elasticities [the proportionate effects on mortality and YLL of a proportionate change in PBC expenditure (see *Including quality-of-life effects during disease* for details of how these estimates can be applied to measures of QALY burden in all PBCs)].

u. See *Including quality-of-life effects during disease* for how PBC level effects can be allocated to the contributing ICD-10 codes and how measures of QALY burden for each ICD-10 code can be established.

v. HES costs only account for 16.8% of total costs in PBC 5 and only explain 5.9% of the variance in PBC costs across PCTs, therefore it seems unlikely that a large proportion of investment and disinvestment in this PBC has been associated with these ICD-10 codes.

w. Although the published evidence suggests that investment and disinvestment opportunities in this PBC tend to be much more valuable than the implied cost per QALY, we have little information on the particular investments and disinvestments that were actually made by PCTs. The review of local data sources (see *Addendum 2: the role of data on local NHS decisions*) revealed very little routinely collected information about specific investments and disinvestments beyond more aggregate measures of spending. In common with other PBCs, there will inevitably be inefficient, ineffective or even iatrogenic practice (e.g. due to poor diagnosis and inappropriate prescribing). Insofar as these types of activities are sensitive to changes in PBC expenditure this will tend to increase the cost per QALY associated with changes in expenditure in this PBC. Whether or not both the extent of these inefficiencies and their sensitivity to changes in expenditure are sufficient to increase the cost per QALY above £13,876 is unclear, although it seems unlikely. Note that the effects of the scale and

sensitivity to expenditure of inefficient or even harmful practice in the other PBCs where outcome equations could be specified are already captured in the estimated outcome elasticities.

x. Professor Craig Currie and Sara Jenkins-Jones.

y. This represents six fewer than the incidence data as in these instances the end dates for the disease were beyond the end of the data collection period.

z. Mapping algorithms were provided by the NHS Connecting for Health group, see www.connectingforhealth.nhs.uk/systemsandservices/data/clinicalcoding/crossmap for more details.

aa. Representing instantaneous, 1 month, 1 year, 5 years and lifelong.

ab. For more information on access to the toolkit see WHO.[156]

ac. For more information on the surveys and the data they collect see Department of Health.[158]

ad. This contrast was informed by our clinical representative (Dr Charlotte Haylock, York Teaching Hospital NHS Foundation Trust, 2012, personal communication).

ae. Estimate by Tim Kendal.

af. This view was informed by our clinical advisors.

ag. Although there was insufficient mortality available at PCT level to estimate outcome elasticities for the other PBCs, the measure of QALY burden in some of these PBCs does include some mortality (based on ONS data). Therefore, applying a proportionate effect to measures of QALY burden disease of will include some mortality and life-year effects although they represent only a small proportion of the total QALY effects.

ah. Information about the age, gender and the incidence of sequelae associated with different diseases within a PBC are only available for U-codes which can be mapped to groups of three-digit ICD-10 codes. Also, allocating PBC-level effects to ICD-10 code was based on the proportion of the total PBC population within each contributing ICD-10 code because PBC costs are not available at ICD-10 code level across PCTs. Although costs from HES data are available at ICD-10 code level, they are only a small component of total PBC costs and contribute very little to the variability in PBC costs across PCTs especially in those PBCs where mortality effects could not be estimated (also see *Chapter 4* notes ap and av and *Addendum 1: data sources*).

References

1. Culyer A, McCabe C, Briggs A, Claxton K, Buxton M, Akehurst R, *et al.* Searching for a threshold, not setting one: the role of the National Institute for Health and Care Excellence. *J Health Serv Res Policy* 2007;**12**:56–8. http://dx.doi.org/10.1258/135581907779497567
2. McCabe C, Claxton K, Culyer AJ. The NICE cost-effectiveness threshold – what it is and what that means. *Pharmacoeconomics* 2008;**26**:733–44. http://dx.doi.org/10.2165/00019053-200826090-00004
3. National Institute for Health and Care Excellence (NICE). *Guide to the Methods of Technological Appraisal*. London: NICE; 2008.
4. House of Commons Health Committee. *NICE: First report of the Health Committee 2007–2008*. HC27-I. London: The Stationery Office; 2008.
5. National Institute for Health and Care Excellence (NICE). *Guide to the Methods of Technological Appraisal*. London: NICE; 2004.
6. Devlin N, Parkin D. Does NICE have a cost-effectiveness threshold and what other factors influence its decisions? A binary choice analysis. *Health Econ* 2004;**13**:437–52. http://dx.doi.org/10.1002/hec.864
7. Gafni A, Birch S. Guidelines for the adoption of new technologies – a prescription for uncontrolled growth in expenditures and how to avoid the problem. *CMAJ* 1993;**148**:913–17.
8. Williams A. *What Could be Nicer than NICE? OHE Annual Lecture*. London: Office of Health Economics; 2004.
9. Drummond M, Torrance G, O'Brien BJ, Stoddard G. *Methods for the Economic Evaluation of Health Care Programmes*. 3rd edn. Oxford University Press; 2005.
10. Birch S, Gafni A. Changing the problem to fit the solution: Johannesson and Weinstein's (mis) application of economics to real world problems. *J Health Econ* 1993;**12**:469–76. http://dx.doi.org/10.1016/0167-6296(93)90006-Z
11. Johannesson M, Weinstein MC. On the decision rules of cost-effectiveness analysis. *J Health Econ* 1993;**12**:459–67. http://dx.doi.org/10.1016/0167-6296(93)90005-Y
12. Department of Health. *A New Value-Based Approach to the Pricing of Branded Medicines – a Consultation*. London: Department of Health; 2010.
13. National Institute for Health and Care Excellence. *First Report of the Health Committee 2007–2008*. London: The Stationery Office; 2008.
14. Weinstein M, Zeckhauser R. Critical ratios and efficient allocation. *J Public Econ* 1973;**2**:147–57. http://dx.doi.org/10.1016/0047-2727(73)90002-9
15. Stinnett AA, Paltiel AD. Mathematical programming for the efficient allocation of health care resources. *J Health Econ* 1996;**15**:641–53. http://dx.doi.org/10.1016/S0167-6296(96)00493-6
16. Epstein D, Chalabi Z, Claxton K, Sculpher MJ. Efficiency, equity and budgetary policies: informing decisions using mathematical programming. *Med Decis Making* 2007;**27**:128–37. http://dx.doi.org/10.1177/0272989X06297396
17. Abelson P. The value of life and health for public policy. *Econ Record* 2003;**79**:S2–13. http://dx.doi.org/10.1111/1475-4932.00087

18. Bobinac A, van Exel NJ, Rutten FF, Brouwer WB. Willingness to pay for a quality-adjusted life-year: the individual perspective. *Value Health* 2010;**13**:1046–55. http://dx.doi.org/10.1111/j.1524-4733.2010.00781.x

19. Byrne MM, O'Malley K, Suarez-Almazor ME. Willingness to pay per quality-adjusted life-year in a study of knee osteoarthritis. *Med Decis Making* 2005;**25**:655–66. http://dx.doi.org/10.1177/0272989X05282638

20. Dolan P, Shaw R, Tsuchiya A, Williams A. QALY maximisation and people's preferences: a methodological review of the literature. *Health Econ* 2004;**14**:197–208. http://dx.doi.org/10.1002/hec.924

21. Green C, Gerard K. Exploring the social value of health-care interventions: a stated preference discrete choice experiment. *Health Econ* 2009;**18**:951–76. http://dx.doi.org/10.1002/hec.1414

22. Groot W, van den Brink HM. The value of health. *BMC Health Serv Res* 2008;**8**:136.

23. Gyrd-Hansen D. Willingness to pay for a QALY. *Health Econ* 2003;**12**:1049–60. http://dx.doi.org/10.1002/hec.799

24. Gyrd-Hansen D. Willingness to pay for a QALY – theoretical and methodological issues. *Pharmacoeconomics* 2005;**23**:423–32. http://dx.doi.org/10.2165/00019053-200523050-00002

25. Johnson FR, Backhouse M. Eliciting stated preferences for health-technology adoption criteria using paired comparisons and recommendation judgments. *Value Health* 2006;**9**:303–11. http://dx.doi.org/10.1111/j.1524-4733.2006.00119.x

26. King JT, Tsevat J, Lave JR, Roberst MS. Willingness to pay for a quality-adjusted life-year: Implications for societal health care resource allocation. *Med Decis Making* 2005;**25**:667–77. http://dx.doi.org/10.1177/0272989X05282640

27. Lieu TA, Ray GT, Ortega-Sanchez IR, Kleinman K, Rusinak D, Prosser LA. Willingness to pay for a QALY based on community member and patient preferences for temporary health states associated with Herpes Zoster. *Pharmacoeconomics* 2009;**27**:1005–16. http://dx.doi.org/10.2165/11314000-000000000-00000

28. Mason H, Jones-Lee M, Donaldson C. Modelling the monetary value of a qaly: a new approach based on UK data. *Health Econ* 2009;**18**:933–50. http://dx.doi.org/10.1002/hec.1416

29. Pinto-Prades JL, Loomes G, Brey R. Trying to estimate a monetary value for the QALY. *J Health Econ* 2009;**28**:553–62. http://dx.doi.org/10.1016/j.jhealeco.2009.02.003

30. Shiroiwa T, Sung YK, Fukuda T, Lang HC, Bae SC, Tsutani K. International survey on willingness-to-pay (wtp) for one additional qaly gained: what is the threshold of cost effectiveness? *Health Econ* 2010;**19**:422–37. http://dx.doi.org/10.1002/hec.1481

31. Yaesoubi R, Roberts SD. A game-theoretic framework for estimating a health purchaser's willingness-to-pay for health and for expansion. *Health Care Manag Sci* 2010;**13**:358–77. http://dx.doi.org/10.1007/s10729-010-9135-6

32. Polsky D. Does willingness to pay per quality-adjusted life-year bring us closer to a useful decision rule for cost-effectiveness analysis? *Med Decis Making* 2005;**25**:605–6. http://dx.doi.org/10.1177/0272989X05283136

33. Smith RD, Richardson J. Can we estimate the 'social' value of a QALY? Four core issues to resolve. *Health Policy* 2005;**74**:77–84. http://dx.doi.org/10.1016/j.healthpol.2004.12.009

34. Hirth RA, Chernew ME, Miller E, Fendrick AM, Weissert WG. Willingness to pay for a quality-adjusted life-year: in search of a standard. *Med Decis Making* 2000;**20**:332–42. http://dx.doi.org/10.1177/0272989X0002000310

35. Haninger K, Hammitt J. *Willingness to Pay for Quality-Adjusted Life Years: Empirical Inconsistency Between Cost-effectiveness Analysis and Economic Welfare Theory*. France: Organisation for Economic Co-operation and Development; 2006.

36. Baker R, Bateman I, Donaldson C, Jones-Lee M, Lancsar E, Loomes G, *et al.* Weighting and valuing quality-adjusted life-years using stated preference methods: preliminary results from the Social Value of a QALY Project. *Health Technol Assess* 2010;**14**(27).

37. Claxton K, Walker S, Sculpher MJ, Palmer S. *Appropriate Perspectives for Heath Care Decisions. CHE Research Paper 54*. York: Centre for Health Economics, University of York; 2010.

38. Rawlins MD, Culyer AJ. National Institute for Clinical Excellence and its value judgments. *BMJ* 2004;**329**:224–7. http://dx.doi.org/10.1136/bmj.329.7459.224

39. Rawlins MD, Barnett D, Stevens A. Pharmacoeconomics: NICE's approach to decision-making. *Br J Clin Pharmacol* 2010;**70**:346–9. http://dx.doi.org/10.1111/j.1365-2125.2009.03589.x

40. Tappenden P, Brazier J, Ratcliffe J, Chilcott J. A stated preference binary choice experiment to explore NICE decision making. *Pharmacoeconomics*, 2007;**25**:685–93. http://dx.doi.org/10.2165/00019053-200725080-00006

41. National Institute for Health and Care Excellence (NICE). *Appraising Life Extending End-of-Life Treatments*. London: NICE; 2009.

42. National Institute for Health and Care Excellence (NICE). *Draft Guide to the Methods of Technology Appraisal*. London: NICE; 2012.

43. House of Commons Health Committee. *NICE Response to the First Report of Session 2007–2008*. London: The Stationery Office; 2008.

44. House of Commons Health Committee. *The Government's Response to the Health Select Committee's First Report of Session 2007–08 on the National Institute for Health and Care Excellence*. London: The Stationery Office; 2008.

45. Braithwaite R, Roberts M. *$50,000 per QALY: Inertia, Indifference, or Irrationality?* Presented at the Annual Meeting of the Society for Medical Decision Making, Atlanta, GA, 2004.

46. Birch S, Gafni A. The biggest bang for the buck or bigger bucks for the bang: the fallacy of the cost-effectiveness threshold. *J Health Serv Res Policy* 2006;**11**:46–51. http://dx.doi.org/10.1258/135581906775094235

47. Collier J. Parliamentary review asks NICE to do better still. *BMJ* 2008;**336**:53–8. http://dx.doi.org/10.1136/bmj.39454.496748.80

48. Towse A. Should NICE's threshold range for cost per QALY be raised? Yes. *BMJ* 2009;**338**:268–9. http://dx.doi.org/10.1136/bmj.b181

49. Appleby J, Devlin N, Parkin D, Buxton M, Chalkidou K. Searching for cost effectiveness thresholds in the NHS. *Health Policy* 2009;**91**:239–45. http://dx.doi.org/10.1016/j.healthpol.2008.12.010

50. Hughes DA, Ferner RE. New drugs for old: disinvestment and NICE. *BMJ* 2010;**340**:690–2. http://dx.doi.org/10.1136/bmj.c572

51. Buxton M. How much are health-care systems prepared to pay to produce a QALY? *Eur J Health Econ* 2005;**6**:285–7. http://dx.doi.org/10.1007/s10198-005-0325-y

52. Elshaug A, Moss JR, Littlejohns P, Karnon J, Merlin TL, Hiller JE. Identifying existing health care services that do not provide value for money. *Med J Aust* 2009;**190**:269–73.

53. Laupacis A, Feeny D, Detsky AS, Tugwell PX. How attractive does a new technology have to be to warrant adoption and utilization – tentative guidelines for using clinical and economic evaluations. *CMAJ* 1992;**146**:473–81.

54. Birch S, Gafni A. Cost-effectiveness ratios – in a league of their own. *Health Policy* 1994;**28**:133–41. http://dx.doi.org/10.1016/0168-8510(94)90031-0

55. Drummond M, Torrance G, Mason J. Cost-effectiveness league tables – more harm than good. *Soc Sci Med* 1993;**37**:33–40. http://dx.doi.org/10.1016/0277-9536(93)90315-U

56. Appleby J, Devlin N, Parkin D. NICE's cost effectiveness threshold – how high should it be? *BMJ* 2007;**335**:358–9. http://dx.doi.org/10.1136/bmj.39308.560069.BE

57. Martin S, Rice N, Smith P. *The Link Between Health Care Spending and Health Outcomes: Evidence from English Programme Budgeting Data. CHE Research Paper 24*. York: Centre for Health Economics; 2007.

58. Martin S, Rice N, Smith P. *Further Evidence on the Link Between Health Care Spending and Health Outcomes in England. CHE Research Paper 32*. York: Centre for Health Economics; 2007.

59. Martin S, Rice N, Smith P. *The Link Between Health Care Spending and Health Outcomes for the New English Primary Care Trusts. CHE Research Paper 42*. York: Centre for Health Economics; 2008.

60. Martin S, Rice N, Smith P. Does health care spending improve health outcomes? *J Health Econ* 2008;**27**:826–42. http://dx.doi.org/10.1016/j.jhealeco.2007.12.002

61. Martin S, Smith P. *How Good at Commissioning Health are English Primary Care Trusts? A Preliminary Statistical Analysis. Report to the Health Foundation*. London: The Health Foundation; 2009.

62. Martin S, Rice N, Smith P. *Panel Data Estimates of the Link Between Health Care Spending and Health Outcomes for English Primary Care Trusts*. York: Centre for Health Economics; 2010.

63. Martin S, Rice N, Smith P. Comparing costs and outcomes across programmes of health care. *Health Econ* 2012;**21**:316–37. http://dx.doi.org/10.1002/hec.1716

64. Cochrane AL, St. Leger AS, Moore F. Health service 'input' and mortality 'output' in developed countries. *J Epidemiol Community Health* 1997;**51**:344–8 [Reprinted from *J Epidemiol Community Health* 1968;**32**:200–5]. http://dx.doi.org/10.1136/jech.51.4.344

65. Young FW. An explanation of the persistent doctor–mortality association. *J Epidemiol Community Health* 2001;**55**:80–4. http://dx.doi.org/10.1136/jech.55.2.80

66. St Leger S. The anomaly that finally went away? *J Epidemiol Community Health* 2001;**55**:79. http://dx.doi.org/10.1136/jech.55.2.79

67. Nolte E, McKee M. *Does Health Care Save Lives*? London: The Nuffield Trust; 2004.

68. Gravelle HSE, Backhouse ME. International cross-section analysis of the determination of mortality. *Soc Sci Med* 1987;**25**:427–41. http://dx.doi.org/10.1016/0277-9536(87)90167-5

69. Cremieux PY, Ouellette P, Pilon C. Health care spending as determinants of health outcomes. *Health Econ* 1999;**8**:627–39. http://dx.doi.org/10.1002/(SICI)1099-1050(199911)8:7<627::AID-HEC474>3.0.CO;2-8

70. Nixon J, Ulmann P. The relationship between health care expenditure and health outcomes. Evidence and caveats for a causal link. *Eur J Health Econ* 2006;**7**:7–18. http://dx.doi.org/10.1007/s10198-005-0336-8

71. Bokhari FA, Gai Y, Gottret P. Government health expenditures and health outcomes. *Health Econ* 2007;**16**:257–73. http://dx.doi.org/10.1002/hec.1157

72. Moreno-Serra R, Smith PC. *The Effects of Health Coverage on Population Outcomes: A Country-Level Panel Data analysis*. Results for Development Institute, Washington DC, Working Paper, 2011.

73. Department of Health. *NHS Finance Manual*. December 2005 edition. URL: www.info.doh.gov.uk/doh/finman.nsf (accessed 12 January 2012).

74. Department of Health. *PCT Recurrent Revenue Allocations Exposition Book: 2009/10 and 2010/11*. London: Department of Health; 2009.

75. Smith PC, Rice N, Carr-Hill R. Capitation funding in the public sector. *J R Stat Soc Series A* 2001;**164**:217–41. http://dx.doi.org/10.1111/1467-985X.00200

76. Department of Health. *Recurrent Resource Allocations: 2006/07, 2007/08*. London: Department of Health; 2005.

77. National Audit Office (NAO). *Good Governance Report: Review of Programme Budgeting*. London: NAO; 2008.

78. Appleby J, Harrison T, Foot C, Smith A, Gilmour S. *Explaining Variations in Primary Care Trusts' Spending on Cancer Services*. London: The King's Fund; 2011.

79. Lakhani A, Olearnik H, Eayres DE. *Compendium of Clinical and Health Indicators: Data Definitions and User Guide for Computer Files*. London: National Centre for Health Outcomes Development; 2006.

80. Office for National Statistics. *Census 2001: General Report for England and Wales*. London: Office for National Statistics; 2005.

81. Shea J. Instrumental relevance in multivariate linear models: a simple measure. *Rev Econ Stat* 1997;**79**:348–52. http://dx.doi.org/10.1162/rest.1997.79.2.348

82. Stock JH, Yogo M. *Testing for Weak Instruments in Linear IV Regression. NBER Technical Working Paper 284*. New York, NY: Cambridge University Press; 2002.

83. Ramsey JB. Tests for specification errors in classical linear least-squares regression analysis. *J R Stat Soc Series B* 1969;**31**:350.

84. Pesaran MH, Taylor LW. Diagnostics for IV regressions. *Oxford Bull Econ Stat* 1999;**61**:255. http://dx.doi.org/10.1111/1468-0084.00128

85. Durbin J. Errors in variables. *Rev Int Stat Inst* 1954;**22**:23–32. http://dx.doi.org/10.2307/1401917

86. Dixon J, Smith P, Gravelle H, Martin S, Bardsley M, Rice N, *et al.* A person based formula for allocating commissioning funds to general practices in England: development of a statistical model. *BMJ* 2011;**343**:d6608.

87. Curtis L. *Unit Costs of Health and Social Care 2011*. Canterbury: PSSRU, University of Kent; 2011.

88. Conley TG, Hansen CB, Rossi PE. Plausibly exogenous. *Rev Econ Stat* 2012;**94**:260–72. http://dx.doi.org/10.1162/REST_a_00139

89. Small DS. Sensitivity analysis for instrumental variables regression with overidentifying restrictions. *J Am Stat Assoc* 2007;**102**:1049–58. http://dx.doi.org/10.1198/016214507000000608

90. Office for National Statistics. *Figures for England. National Life Tables 2006–2008*. URL: www.ons.gov.uk/ons/rel/subnational-health4/life-expec-at-birth-age-65/2004-06-to-2008-10/statistical-bulletin.html#tab-National-life-expectancy (accessed 12 January 2013).

91. Wailoo AD, Tosh SJ. *The Incorporation of Health Benefits in Cost Utility Analysis Using the EQ-5D: Report by the Decision Support Unit*. Sheffield: School of Health and Related Research, University of Sheffield; 2010.

92. Dolan P, Gudex C, Kind P, Williams A. *A Social Tariff for EuroQol: Results from a UK General Population Survey*. CHE discussion paper 138. York: University of York; 1995.

93. Currie CJ, McEwan P, Peters JR, Patel TC, Dixon S. The routine collation of health outcomes data from hospital treated subjects in the Health Outcomes Data Repository (HODaR): descriptive analysis from the first 20,000 subjects. *Value Health* 2005;**8**:581–90. http://dx.doi.org/10.1111/j.1524-4733.2005.00046.x

94. Cohen JW, Monheit AC, Beauregard KM, Cohen SB, Lefkowitz DC, Potter DE, *et al.* The Medical Expenditure Panel Survey: a national health information resource. *Inquiry* 1996;**33**:373–89.

95. Claxton K, Palmer S, Longworth L, Bojke L, Griffin S, McKenna C, *et al.* Informing a decision framework for when NICE should recommend the use of health technologies only in the context of an appropriately designed programme of evidence development. *Health Technol Assess* 2012;**16**(46).

96. Claxton K. The irrelevance of inference: a decision-making approach to the stochastic evaluation of health care technologies. *J Health Econ* 1999;**18**:341–64. http://dx.doi.org/10.1016/S0167-6296(98)00039-3

97. Jackson C, Bojke L, Thompson S, Claxton K, Sharples L. A framework for addressing structural uncertainty in decision models. *Med Decis Making* 2011;**31**:662–74. http://dx.doi.org/10.1177/0272989X11406986

98. Soares MO, Bojke L, Dumville J, Iglesias C, Cullum N, Claxton K. Methods to elicit experts' beliefs over uncertain quantities: application to a cost effectiveness transition model of negative pressure wound therapy for severe pressure ulceration. *Stat Med* 2011;**30**:2363–80. http://dx.doi.org/10.1002/sim.4288

99. Claxton K, Lindsay AB, Buxton MJ, Culyer AJ, McCabe C, Walker S, *et al.* Value based pricing for NHS drugs: an opportunity not to be missed? *BMJ* 2008;**336**:251–4. http://dx.doi.org/10.1136/bmj.39434.500185.25

100. Claxton K, Sculpher MJ, Carroll S. *Value-based Pricing for Pharmaceuticals: Its Role, Specification and Prospects in a Newly Devolved NHS. CHE Research Paper 60*. York: Centre for Health Economics, University of York; 2011. URL: www.york.ac.uk/media/che/documents/papers/researchpapers/CHERP60_value_based_pricing_for_pharmaceuticals.pdf

101. Maynard A, Street A. Seven years of feast, seven years of famine: boom to bust in the NHS? *BMJ* 2006;**332**:906–8. http://dx.doi.org/10.1136/bmj.332.7546.906

102. Office for Fair Trading. *The Pharmaceutical Price Regulation Scheme. An OFT Market Study. VBP Report 2007*. London: Office of Fair Trading; 2007.

103. Claxton K, Paulden M, Gravelle HSE, Brouwer W, Culyer AJ. Discounting and decision making in the economic evaluation of health care technologies. *Health Econ* 2011;**20**:2–15. http://dx.doi.org/10.1002/hec.1612

104. Paulden M, Claxton K. Budget allocation and the revealed social rate of time preference for health. *Health Econ* 2011;**24**:612–18.

105. National Institute for Health and Care Excellence (NICE). *TA237: Ranibizumab for the Treatment of Diabetic Macular Oedema*. London: NICE; 2011.

106. National Institute for Health and Care Excellence (NICE). *Macular Oedema (Diabetic) – Ranibizumab (Rapid Review of TA237): Appraisal Consultation Document*. London: NICE; 2012.

107. Novartis. *Single Technology Appraisal (STA) Manufacturer Submission: Lucentis® (Ranibizumab) for the Treatment of Visual Impairment due to Diabetic Macular Oedema (DMO)*. Chamberley: Novartis; 2010.

108. National Institute for Health and Care Excellence (NICE). *Technology Appraisal TA237: Ranibizumab for the Treatment of Diabetic Macular Oedema*. URL: http://guidance.nice.org.uk/TA237 (accessed 12 January 2013).

109. National Institute for Health and Care Excellence (NICE). *Rapid Review of TA237: Ranibizumab for the Treatment of Diabetic Macular Oedema*. URL: http://guidance.nice.org.uk/TA/Wave23/41 (accessed 12 January 2013).

110. Broome J. Trying to value a life. *J Public Econ* 1978;**9**:91–100. http://dx.doi.org/10.1016/0047-2727(78)90029-4

111. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med* 2001;**16**:606–13. http://dx.doi.org/10.1046/j.1525-1497.2001.016009606.x

112. Spitzer RL, Kroenke K, Williams JB, Lowe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med* 2006;**166**:1092–7. http://dx.doi.org/10.1001/archinte.166.10.1092

113. World Health Organization (WHO). Global Burden of Disease Study 2010. *Lancet* 2012.

114. Barrett A, Roques T, Small M, Smith R. How much will Herceptin really cost? *BMJ* 2006;**333**:1118–20. http://dx.doi.org/10.1136/bmj.39008.624051.BE

115. Brock DW. How much is more life worth? *Hastings Cent Rep* 2006;**36**:17–19. http://dx.doi.org/10.1353/hcr.2006.0036

116. Brouwer W, van Exel J, Baker R, Donaldson C. The new myth – the social value of the QALY. *Pharmacoeconomics* 2008;**26**:1–4. http://dx.doi.org/10.2165/00019053-200826010-00001

117. Chambers JD, Neumann PJ, Buxton MJ. Does medicare have an implicit cost-effectiveness threshold? *Med Decis Making* 2010;**30**:E14–27. http://dx.doi.org/10.1177/0272989X10371134

118. Cohen J, Looney W. Re: how much is life worth: cetuximab, non-small cell lung cancer, and the $440 billion question. *J Ntl Cancer Inst* 2010;**102**:1044–8. http://dx.doi.org/10.1093/jnci/djq246

119. Eichler HG, Kong SX, Gerth WC, Mavros P, Jonsson B. Use of cost-effectiveness analysis in health-care resource allocation decision-making: How are cost-effectiveness thresholds expected to emerge? *Value Health* 2004;**7**:518–28. http://dx.doi.org/10.1111/j.1524-4733.2004.75003.x

120. Gafni A, Birch S. Incremental cost-effectiveness ratios (ICERs): the silence of the lambda. *Soc Sci Med* 2006;**62**:2091–100. http://dx.doi.org/10.1016/j.socscimed.2005.10.023

121. Garber A, Phelps C. Economic foundations of cost-effectiveness analysis. *J Health Econ* 1997;**16**:1–31. http://dx.doi.org/10.1016/S0167-6296(96)00506-1

122. Grosse SD. Assessing cost-effectiveness in healthcare: history of the $50,000 per QALY threshold. *Expert Rev Pharmacoecon Outcomes Res* 2008;**8**:165–78. http://dx.doi.org/10.1586/14737167.8.2.165

123. Johannesson M, Meltzer D. Some reflections on cost-effectiveness analysis. *Health Econ* 1998;**7**:1–7. http://dx.doi.org/10.1002/(SICI)1099-1050(199802)7:1<1::AID-HEC327>3.0.CO;2-U

124. Johnson FR. Einstein on willingness to pay per QALY: is there a better way? *Med Decis Making* 2005;**25**:607–8. http://dx.doi.org/10.1177/0272989X05283084

125. Kaplan R, Bush J. Health-related quality-of-life measurement for evaluation research and policy analysis. *Health Psychol* 1982;**1**:61–80. http://dx.doi.org/10.1037/0278-6133.1.1.61

126. Laufer F. Thresholds in cost-effectiveness analysis – more of the story. *Value Health* 2005;**8**:86–7. http://dx.doi.org/10.1111/j.1524-4733.2005.08103.x

127. Mauskopf J, Rutten F, Schonfeld W. Cost-effectiveness league tables – valuable guidance for decision makers? *Pharmacoeconomics* 2003;**21**:991–1000. http://dx.doi.org/10.2165/00019053-200321140-00001

128. Maynard A, Bloor K. The future role of NICE. *BMJ* 2010;**341**:1006–7. http://dx.doi.org/10.1136/bmj.c6286

129. Rascati KL. The $64,000 question – what is a quality-adjusted life-year worth? *Clin Ther* 2006;**28**:1042–3. http://dx.doi.org/10.1016/j.clinthera.2006.07.002

130. Towse A, Pritchard C, Devlin N. *Cost-Effectiveness Thresholds: Economic and Ethical Issues*. London: Office of Health Economics, The King's Fund; 2002.

131. O'Brien BJ, Gertsen K, Willan AR, Faulkner LA. Is there a kink in consumers' threshold value for cost-effectiveness in health care? *Health Econ* 2002;**11**:175–80. http://dx.doi.org/10.1002/hec.655

132. Speight J, Reaney M. Wouldn't it be NICE to consider patients' views when rationing health care? *BMJ* 2009;**338**:297. http://dx.doi.org/10.1136/bmj.b85

133. Raftery J. Should NICE's threshold range for cost per QALY be raised? No. *BMJ* 2009;**338**:268–9. http://dx.doi.org/10.1136/bmj.b185

134. Bridges JFP, Onukwugha E, Mullins CD. Healthcare rationing by proxy cost-effectiveness analysis and the misuse of the $50 000 threshold in the US. *Pharmacoeconomics* 2010;**28**:175–84. http://dx.doi.org/10.2165/11530650-000000000-00000

135. Mason AR, Drummond MF. Public funding of new cancer drugs: is NICE getting nastier? *Eur J Cancer* 2009;**45**:1188–92. http://dx.doi.org/10.1016/j.ejca.2008.11.040

136. Ubel PA, Hirth RA, Chernew ME, Fendrick AM. What is the price of life and why doesn't it increase at the rate of inflation? *Arch Intern Med* 2003;**163**:1637–41. http://dx.doi.org/10.1001/archinte.163.14.1637

137. Vernon JA, Goldberg R, Golec J. Economic evaluation and cost-effectiveness thresholds signals to firms and implications for R&D investment and innovation. *Pharmacoeconomics* 2009;**27**:797–806. http://dx.doi.org/10.2165/11313750-000000000-00000

138. World Health Organization (WHO). *The World Health Report: Reducing Risks, Promoting Healthy Life*. Geneva: WHO; 2002.

139. Lee CP, Chertow GM, Zenios SA. An empiric estimate of the value of life: updating the renal dialysis cost-effectiveness standard. *Value Health* 2009;**12**:80–7. http://dx.doi.org/10.1111/j.1524-4733.2008.00401.x

140. Gerdtham U, Jonsson B. International Comparisons of Health Expenditure. In Culyer A, Newhouse J, editors. *Handbook of Health Economics*. Amsterdam: Elsevier; 2000.

141. Fisher ES, Welch HG. Avoiding the unintended consequences of growth in medical care – how might more be worse? *JAMA* 1999;**281**:446–53. http://dx.doi.org/10.1001/jama.281.5.446

142. Or Z. *Exploring the Effects of Health Care on Mortality Across OECD Countries*. OECD Labour Market and Social Policy Occasional Paper No. 46. Paris: OECD; 2001.

143. Bound J, Jaeger DA, Baker RM. Problems with instrumental variables estimation when the correlation between the instruments and the endogenous explanatory variable is weak. *JAMA* 1995;**90**:443–50.

144. Staiger D, Stock JH. Instrumental variables regression with weak instruments. *Econometrica* 1997;**65**:557–86.

145. Cragg JG, Donald SG. Testing identifiability and specification in instrumental variable models. *Econometric Theory* 1993;**9**:222–40. http://dx.doi.org/10.1017/S0266466600007519

146. Wooldridge J. *Econometric Analysis of Cross Section and Panel Data*. Cambridge: The MIT Press; 2002.

147. Department of Health. *Payment by Results: Tariff Information*. London: Department of Health; 2007.

148. Department of Health. *Unified Exposition Book: 2003/04, 2004/05 and 2005/06 PCT Revenue Resource Limits*. London: Department of Health; 2005.

149. Dixon JY, Smith P, Gravelle M, Martin S, Bardsley M, Rice N, *et al.* A person based formula for allocating commissioning funds to general practices in England: development of a statistical model. *BMJ* 2011;**343**:d6608. http://dx.doi.org/10.1136/bmj.d6608

150. Kovandic T, Schaffer M, Kleck G. *Estimating the Causal Effect of Gun Prevalence on Homicide Rates: A Local Average Treatment Effect Approach*. Discussion paper 3589. Bonn: IZA; 2008.

151. Health and Social Information Centre. *Provisional Monthly Patient Reported Outcome Measures (PROMs) in England: A Guide to PROMs Methodology*. Version 3, 2011. Health and Social Care Information Centre; 2011.

152. Office for National Statistics. *Life Expectance at Birth and at Age 65 By Local Areas in the United Kingdom, 2004-06 to 2008-10*. URL: www.ons.gov.uk/ons/rel/subnational-health4/life-expec-at-birth-age-65/2004-06-to-2008-10/statistical-bulletin.html#tab-National-life-expectancy (accessed 17 April 2014).

153. National Institute for Health and Care Excellence (NICE). *Guide to the Methods of Technological Appraisal*. London: NICE; 2012.

154. Murray C, Lopez AE. *The Global Burden of Disease*. Geneva: World Health Organization, Harvard School of Public Health, World Bank; 1996.

155. World Health Organization (WHO). *The Global Burden of Disease: 2004 Update*. Geneva: WHO; 2008.

156. World Health Organization. *The National Burden of Disease (NBD) Toolkit*. URL: www.who.int/healthinfo/global_burden_disease/tools_nbd_toolkit/en/index.html (accessed 29 April 2014).

157. Mathers C, Bernard C, Iburg K, Inoue M, Ma Fat D, Shibuya K, *et al. Global Burden of Disease in 2002: Data Sources, Methods and Results*. GPE Discussion Paper No. 54. Geneva: World Health Organization; 2003.

158. Health and Social Care Information Centre. *Health Surveys for England*. URL: www.hscic.gov.uk/article/3659/Health-Survey-for-England (accessed 29 April 2014).

159. Appleby J, Devlin N. *Getting the Most Out of PROMs: Putting Health Outcomes at the Heart of NHS Decision-Making*. London: The King's Fund; 2010.

160. Gutacker N, Bojke C, Daidone S, Devlin N, Parkin D, Street A. Truly inefficient or providing better quality of care? Analysing the relationship between risk-adjusted hospital costs and patients' health outcomes. *Health Econ* 2013;**22**:931–47.

161. Feng Y, Parkin D, Devlin N. *Assessing the Performance of the EQ-VAS in the NHS PROMs Programme*. Research Paper 12/01. London: Office of Health Economics, The King's Fund; 2012.

162. NHS Information Centre. *Provisional Monthly Patient Reported Outcome Measures (PROMs) in England*. Leeds: NHS Information Centre; 2012.

163. Public Health England. *PCT CCG Spend and Outcome Factsheets and Tools (SPOT)*. URL: www.yhpho.org.uk/resource/view.aspx?RID=49488 (accessed 29 April 2014).

164. Public Health England. *NHS Atlas of Variation in Healthcare Services*. URL: www.rightcare.nhs.uk/atlas/index.html (accessed 29 April 2014).

165. *NHS Choices*. URL: www.nhs.uk/Pages/HomePage.aspx (accessed 10 October 2011).

166. National Institute for Health and Care Excellence (NICE). *CG82: Core Interventions in the Treatment and Management of Schizophrenia in Primary and Secondary Care*. London: NICE; 2009.

167. Knapp M, Windmeijer F, Brown J, Kontodimas S, Tzivelekis S, Haro JM, *et al.* Cost-utility analysis of treatment with Olanzapine compared with other antipsychotic treatments in patients with schizophrenia in the Pan-European SOHO study. *Pharmacoeconomics* 2008;**26**:341–58. http://dx.doi.org/10.2165/00019053-200826040-00006

168. Davies LM, Barnes LM, Jones PB, Lewis S, Gaughran F, Hayhurst K, *et al.* A randomized controlled trial of the cost-utility of second-generation antipsychotics in people with psychosis and eligible for clozapine. *Value Health* 2008;**11**:549–62. http://dx.doi.org/10.1111/j.1524-4733.2007.00280.x

169. Bagnall AM, Jones L, Ginnelly L, Lewis R, Glanville J, Gilbody S, *et al.* A systematic review of atypical antipsychotic drugs in schizophrenia. *Health Technol Assess* 2003;**7**(13).

170. Barton GR, Hodgekins J, Mugford M, Jones PBB, Croudace T, Fowler D. Cognitive behaviour therapy for improving social recovery in psychosis: cost-effectiveness analysis. *Schizophr Res* 2009;**112**:158–63. http://dx.doi.org/10.1016/j.schres.2009.03.041

171. National Institute for Health and Care Excellence (NICE). *CG90: Depression the Treatment and Management of Depression in Adults*. London: NICE; 2009.

172. Lenox-Smith A, Greenstreet L, Burslem K, Knight C. Cost effectiveness of venlafaxine compared with generic fluoxetine or generic amitriptyline in major depressive disorder in the UK. *Clin Drug Invest* 2009;**29**:173–84. http://dx.doi.org/10.2165/00044011-200929030-00004

173. Kendrick T, Peveler R, Longworth L, Baldwin D, Moore M, Chatwin J, *et al.* Cost-effectiveness and cost-utility of tricyclic antidepressants, selective serotonin reuptake inhibitors and lofepramine: randomised controlled trial. *Br J Psychiatry* 2006;**188**:337–45. http://dx.doi.org/10.1192/bjp.188.4.337

174. Hatziandreu EJ, Brown RE, Revicki DA, Turner R, Martindale J, Levine S, *et al.* Cost utility of maintenance treatment of recurrent depression with sertraline versus episodic treatment with dothiepin. *Pharmacoeconomics* 1994;**5**:249–68. http://dx.doi.org/10.2165/00019053-199405030-00008

175. Peveler R, Kendrick T, Buxton M, Longworth L, Baldwin D, Moore M, *et al.* A randomised controlled trial to compare the cost-effectiveness of tricyclic antidepressants, selective serotonin reuptake inhibitors and lofepramine. *Health Technol Assess* 2005;**9**(16).

176. Kendrick T, Chatwin J, Dowrick C, Tylee A, Morriss R, Peveler R, *et al.* Randomised controlled trial to determine the clinical effectiveness and cost-effectiveness of selective serotonin reuptake inhibitors plus supportive care, versus supportive care alone, for mild to moderate depression with somatic symptoms in primary care: the THREAD (THREshold for AntiDepressant response) study. *Health Technol Assess* 2009;**13**(22).

177. Simon J, Pilling S, Burbeck R, Goldberg D. Treatment options in moderate and severe depression: decision analysis supporting a clinical guideline. *Br J Psychiatry* 2006;**189**:494–501. http://dx.doi.org/10.1192/bjp.bp.105.014571

178. Kaltenthaler E, Shackley P, Stevens K, Beverley C, Parry G, Chilcott J. A systematic review and economic evaluation of computerised cognitive behaviour therapy for depression and anxiety. *Health Technol Assess* 2002;**6**(22).

179. Kaltenthaler E, Brazier J, De Nigris E, Tumur I, Ferriter M, Beverley C, *et al.* Computerised cognitive behaviour therapy for depression and anxiety update: a systematic review and economic evaluation. *Health Technol Assess* 2006;**10**(33).

180. Hollinghurst S, Peters TJ, Kaur S, Wiles N, Lewis G, Kessler D. Cost-effectiveness of therapist-delivered online cognitive-behavioural therapy for depression: randomised controlled trial. *Br J Psychiatry* 2010;**197**:297–304. http://dx.doi.org/10.1192/bjp.bp.109.073080

181. Mears A, Kendall T, Strathdee G, Sinfield R, Aldridge I. Progress on NICE guideline implementation in mental health trusts: meta-analyses. *Psychiatrist* 2008;**32**:383–7.

182. Rosenheck RA, Leslie DL, Sindelar J, Miller EA, Lin H, Stroup TS, *et al.* Cost-effectiveness of second-generation antipsychotics and perphenazine in a randomized trial of treatment for chronic schizophrenia. *Am J Psychiatry* 2006;**163**:2080–9. http://dx.doi.org/10.1176/appi.ajp.163.12.2080

183. Lambert MT, Copeland LA, Sampson N, Duffy SA. New-onset type-2 diabetes associated with atypical antipsychotic medications. *Prog Neuro-Psychopharmacol Biol Psychiatry* 2006;**30**:919–23. http://dx.doi.org/10.1016/j.pnpbp.2006.02.007

184. Dispensing Doctors Association. *Patent Expiry 2010–11*. URL: www.dispensingdoctor.org/content.php?id=1335 (accessed 3 May 2012).

185. Haas SJ, Hill R, Krum H, Liew D, Tonkin A, Demos L, *et al.* Clozapine-associated myocarditis: a review of 116 cases of suspected myocarditis associated with the use of clozapine in Australia during 1993–2003. *Drug Saf* 2007;**30**:47–57. http://dx.doi.org/10.2165/00002018-200730010-00005

186. Alvir JM, Lieberman JA, Safferman AZ, Schwimmer JL, Schaaf JA. Clozapine-induced agranulocytosis. Incidence and risk factors in the United States. *N Engl J Med* 1993;**329**:162–7. http://dx.doi.org/10.1056/NEJM199307153290303

187. Crawford MJ, Killaspy H, Barnes TRE, Barrett B, Byford S, Clayton K, *et al.* Group art therapy as an adjunctive treatment for people with schizophrenia: multicentre pragmatic randomised trial. *BMJ* 2012;**344**:e846.

188. Kendall T. Treating negative symptoms of schizophrenia. *BMJ* 2012;**344**:e664.

189. Tarrier N, Barrowclough C, Porceddu K, Fitzpatrick E. The Salford Family Intervention Project: relapse rates of schizophrenia at five and eight years. *Br J Psychiatry* 1994;**165**:829–32. http://dx.doi.org/10.1192/bjp.165.6.829

190. Jarbrink K, Kreif N, Benedict A, Locklear J. Quality of life and drug costs associated with switching antipsychotic medication to once-daily extended release quetiapine fumarate in patients with schizophrenia. *Curr Med Res Opin* 2009;**25**:709–16. http://dx.doi.org/10.1185/03007990902738810

191. Davies LM, Lewis S, Jones PB, Barnes TR, Gaughran F, Hayhurst K, *et al.* Cost-effectiveness of first- v. second-generation antipsychotic drugs: results from a randomised controlled trial in schizophrenia responding poorly to previous therapy. *Br J Psychiatry* 2007;**191**:14–22. http://dx.doi.org/10.1192/bjp.bp.106.028654

192. National Institute for Health and Care Excellence (NICE). *CG82: Schizophrenia (Update)*. London: NICE: 2009.

193. National Institute for Health and Care Excellence (NICE). *CG90: Depression in Adults: The Treatment and Management of Depression in Adults*. London: NICE; 2007.

194. Department of Health. *A New Value-Based Approach to the Pricing of Branded Medicines: Government Response to Consultation*. London: Department of Health; 2011.

Appendix 1 Systematic review of the literature on the cost-effectiveness threshold

Systematic review approach

Introduction

The aim of the systematic review was to inform the development of the conceptual framework, as well as the design, implementation and interpretation of the empirical analyses. Rather than define a set of very specific questions to answer through the review, the objective was to characterise the existing literature in terms of the questions addressed and approaches taken. However, it was hoped that insights would be provided on topics including:

- general conceptualisation of the cost-effectiveness threshold
- how NICE's cost-effectiveness threshold should be defined, characterised and operationalised
- approaches to estimating cost-effectiveness thresholds in general and the NICE threshold in particular.

In the initial stages of this systematic review it became clear that the 'traditional' method of conducting systematic searches of existing literature on the topic of the cost-effectiveness threshold would be insufficient to deal with the requirements of this particular study. Here we refer to the 'traditional' method as the practice of finding key terms and medical subject headings (MeSHs) that most accurately capture the range of literature relevant to the topic, while attempting to include as few irrelevant studies as possible (making use of programs such as MEDLINE).

The main weaknesses of using such an approach for a systematic review of this topic is that it requires a pre-existing knowledge of the terms used and topics covered in the current literature. This process has always required a degree of expertise (and luck) as to the strategy taken, including both knowledge of the literature to find likely search terms and skill in the construction of the strategies. The implications of excluding a single key term are potentially equivalent to ignoring vast areas of the literature. In addition, the traditional approach relies on key terms existing that suitably encapsulate the relevant literature. Finding common terms used in literature with potential relevance to the cost-effectiveness threshold was found to be a significant problem as many relevant topics were not specifically aimed at issues relating to the NICE cost-effectiveness threshold (e.g. the Martin *et al.* publications[57–59] which provide a precursor to this project). In addition, due to the wide range of coverage of topics such a 'threshold' and 'cost-effective', any attempts at a systematic review would be either excessively large or result in a clearly limited snap-shot of the existing literature.

As a result a pragmatic approach was taken to the identification of relevant papers, one of 'pearl growing' which can be defined here as the use of existing collections of studies to identify additional relevant parts of the literature. The approach uses a pool of 'initial pearls' to grow the literature both through references and citations until all relevant papers have been discovered. This approach therefore relies on the expertise of the authors of the existing literature to populate the pool of studies rather than the searcher's potentially limited knowledge.

Although this approach of 'pearl growing' was significantly limited by the existing software available and has a time consuming element, it represents an approach that corrects for many of the failings of traditional searches for topics that share the characteristics of the cost-effectiveness threshold.

Systematic review methods

The 'pearl growing' method of systematic review can be characterised into five steps for the identification of relevant papers.

1. Identification and extraction of 'initial pearls'.

    - 'Initial pearls' were identified through consultation with researchers with experience of the cost-effectiveness threshold literature. Fourteen initial pearls were identified through this process. These publications were chosen for their wide-ranging coverage of the topic as well as their anticipated significance.

2. Extraction of citations and references from 'initial pearls'.

    - Citations: Web of Knowledge was selected to perform the citation searches. The reason for this selection was in part due to expert advice from an information specialist as well as brief and non-systematic investigations of citation results from a range of alternative software packages.
    - References: Web of Knowledge was also used for the collection of papers' references.
    - Both citations and references were exported into an EndNote library (EndNote X6, Thomson Reuters, CA, USA) for the purpose of collection and further analysis (exclusion of repeats, title searching and review of the abstracts).

3. Identification of further 'pearls' from cited and referenced papers.

    - Once citations and references of the 'initial pearls' had been collected, they were subjected to a set of investigations to identify further 'pearls'.
    - Papers were excluded based on whether or not the titles or abstracts suggested the paper contained information on five topics of interest. These topics had been previously identified given the objectives of the project and from a review of the 'initial pearls' and included papers were classified by whether or not they could inform:

        - introduction to the cost-effectiveness threshold topic and policy context
        - discussion and debate around the current value use of the threshold
        - potential methods suggested to find a suitable threshold value
        - specific values proposed
        - the use of individual and societal valuations of health gains to inform the value of the threshold.

4. Repetition of citation and reference searches.

    - The process was then repeated for the 'pearls' identified in step 3.
    - This process was repeated until no new 'pearls' were discovered by additional iterations.

5. Manual search of references.

    - To ensure as complete a search had been conducted as possible a retrospective manual search of all of the 'pearls' references was conducted. Any potentially relevant references not discovered previously (most likely due to a mix of user error and limitations with the software used) were added to the analysis at the relevant step and further pearl growing methods applied to them to ensure completeness of results.

Systematic review results

The 'pearl growing' method of systematic review revealed 76 papers deemed relevant. The results from each stage of the process are reported in *Figure 9*. The figure highlights that after four iterations no new relevant papers were identified by the systematic process.

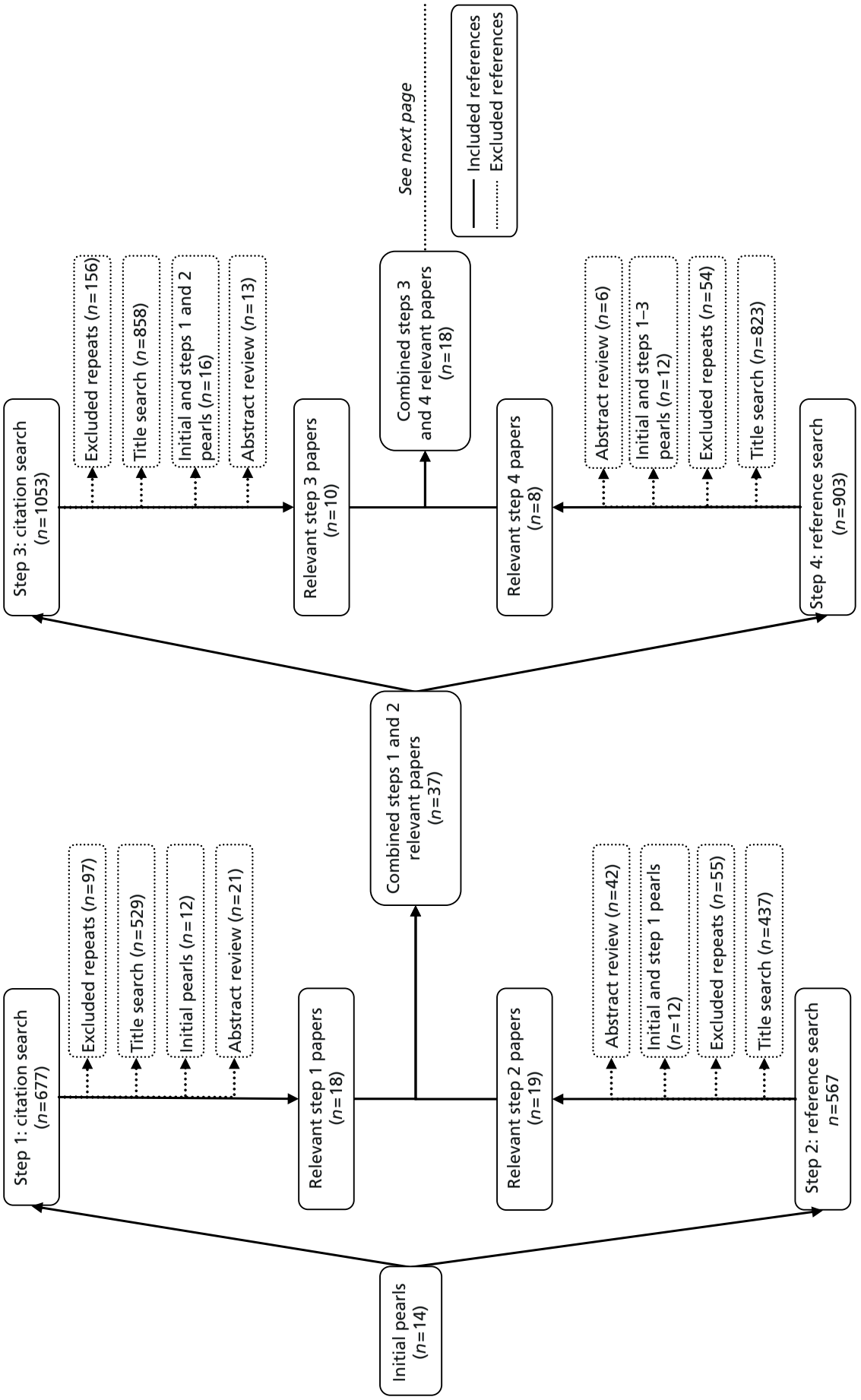


FIGURE 9 Graph showing process results from pearl growing systematic review.

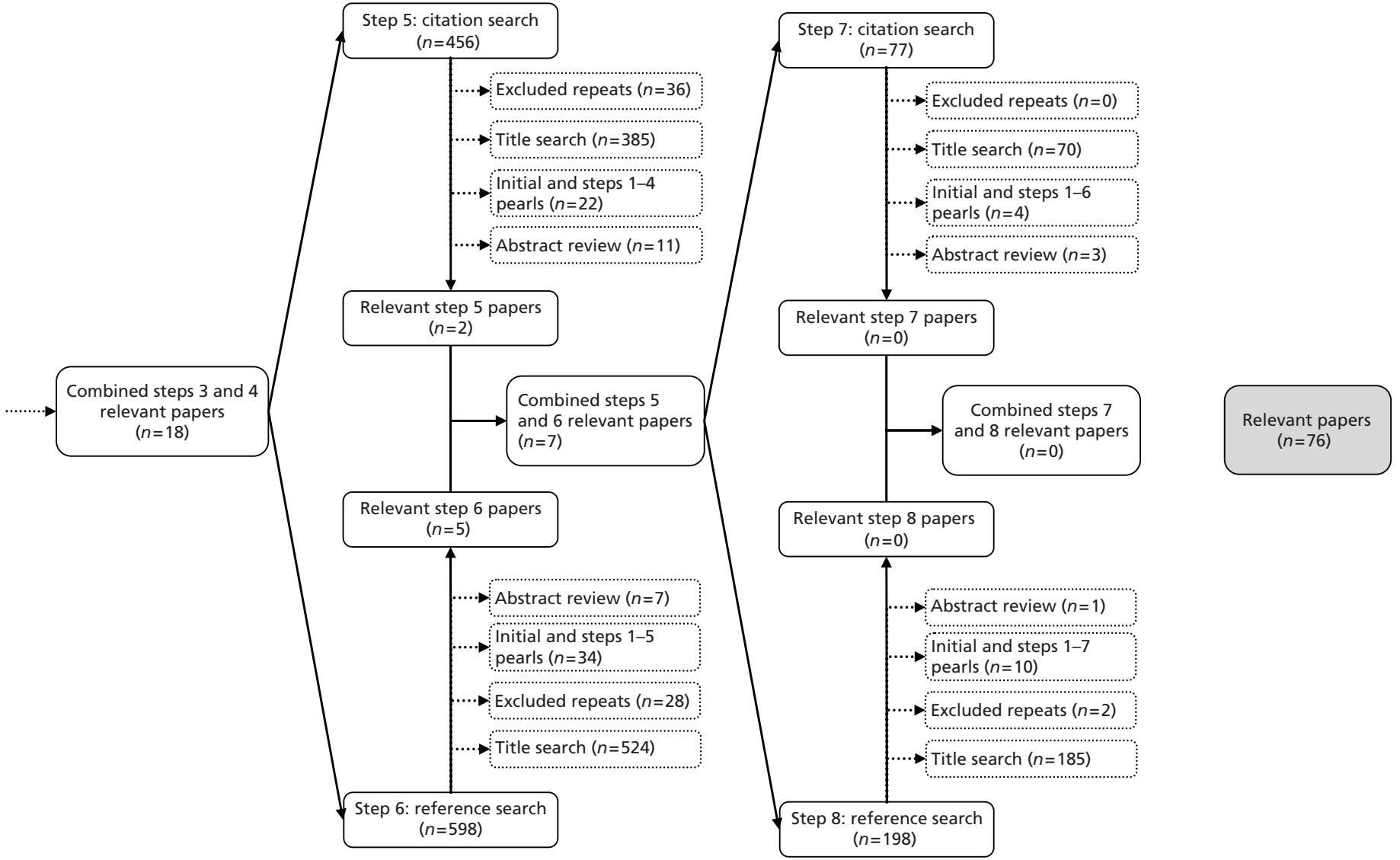


FIGURE 9 Graph showing process results from pearl growing systematic review. (*continued*)

Review of the literature

Introduction and policy context

Due to the broad range of context which the relevant literature covers it is necessary to break down the literature review into several topics, these will be discussed independently. The 76 papers (see *Papers discovered by the literature review* for all of these papers) identified by the systematic review were defined into three different categories:

1. literature covering the introduction to the cost-effectiveness threshold topic and policy context
2. discussion and debate around the current value use of the threshold
3. potential methods suggested to find a suitable threshold value.

These categories were chosen to reflect the broad range of relevant topics and areas of discussion covered by the cost-effectiveness threshold literature. It should be noted that the majority of the literature identified by the literature review fell into the first and last categories, with very few covering multiple categories sufficiently to be discussed in more than one section. The final category will only be discussed briefly as it can be seen as a separate, unrelated approach to the threshold required for purposes of decision-making by NICE.

The majority of papers (34 of the 76 papers discovered) identified in the literature review could be characterised as introducing the idea of a cost-effectiveness threshold (these consist of the very early literature pre-dating NICE) or discussing the policy context through the years.[1–3,5,7,8,15,33,40,46,47,50,52–55,114–130] This section will characterise the main areas of discussion in the literature and briefly describe the key parts of the literature development.

Definition of the cost-effectiveness threshold

An important place to start is the consideration of how the literature has defined the cost-effectiveness threshold. This is important to analyse in the review as not only is it worth ensuring that a good definition has been presented, but it also allows us to assess whether or not the existing literature uses a definition that is both consistent and accurate.

One of the earliest definitions of something resembling the modern interpretation of the cost-effectiveness threshold comes from Weinstein and Zeckhauser.[15] Their paper identifies a 'critical ratio' between monetary costs and a measure of health gains. This critical ratio was argued to represent 'a cut-off point for allocation' of an activity in a budget-constrained public sector entity (p. 1).[15]

A similar, more recent approach to define the threshold is that taken by Towse *et al.*[130] where the author considered a hypothetical budget-constrained health-care sector, with a perfectly informed decision-maker who only considers the cost per QALY of health technologies. Assuming perfect information, the decision-maker is able to rank all of the potential health-care activities based on their cost per QALY. A decision-maker will implement as many of the relatively low cost per QALY activities as possible until the budget is used up. Eventually a point will be reached where society is not willing to pay for a further marginal increase in QALYs and would rather the funding be used on other consumption. The cost per QALY at which this cut-off occurs can be described as the cost-effectiveness threshold as it represents the switching point between an activity being funded and not. As the budget is assumed to be fully responsive, any new technologies with a cost per QALY below this threshold will be funded in the future.

National Institute for Health and Care Excellence and the cost-effectiveness threshold

The use and valuation of a cost-effectiveness threshold by NICE has been controversial. Williams[8] highlighted three events that may be argued to have particularly muddied the water. First, NICE did not set a threshold value by the government at the time of its inception in 1999. This meant that NICE was obliged to come up with a de novo estimate fairly rapidly. Through his set of discussions with NICE,

Williams stated that at the point of inception NICE came up with a value of 'roughly £30,000 per QALY, plus or minus £5000 depending on the specific circumstances' (p. 7)[8]

The second event which Williams refers to was NICE's initial resistance to acknowledging that any form of threshold value existed. Following analyses such as Towse *et al.*[130] and Devlin and Parkin[6] investigating previous NICE decisions and inferring an implicit threshold, NICE began to publish details of its approach to an ICER threshold. The major step was the 2004 *Guide to the Methods of Technological Appraisal*[5] that provided these details, although the definition of the £20,000–30,000 threshold range may be considered loose and open to interpretation. Although the 2004 guide was one of the first official references to the threshold, Sir Michael Rawlins did state at the 2001 NICE Annual General Meeting that the Institute would 'need to be very clear in its reasons for supporting technologies with cost-effectiveness ratios higher than £30,000 per QALY'.[130]

Williams' final event is the often quoted £20,000–30,000 threshold range having never been scientifically justified. Authors such as Rawlins and Culyer[38] have argued that there has never been an empirical basis for the values or any definitive meaning behind the range. They therefore argued that the threshold should not be the only tool for NICE to draw conclusions about new technologies.

The threshold as a range

The idea of such a threshold range has been part of the literature for some time. Kaplan and Bush[125] considered the idea of a less abrupt approach than that suggested by Weinstein and Zeckhauser.[17] Kaplan and Bush[125] investigated a set of early Medicare adoption decisions and presented broad criteria of acceptance based on a set of threshold ranges in terms of cost per additional well-year. These were defined as < $20,000/well-year (cost-effective), $20,000–100,000 (possibly controversial but justifiable), > $100,000 (questionable when compared with other expenditure). However, the authors noted that a $100,000 cut-off was not relevant to the policy decisions at the time and that all results would need significant future investigation. Similarly, Laupacis *et al.*[53] presented five 'grades of recommendation' for decisions about technological reimbursement in Canada.

The conclusions of both of these papers can be represented graphically by *Figure 10*, which is also described or presented in much of the literature (see Rawlins and Culyer,[38] Littlejohn in Towse *et al.*,[130]

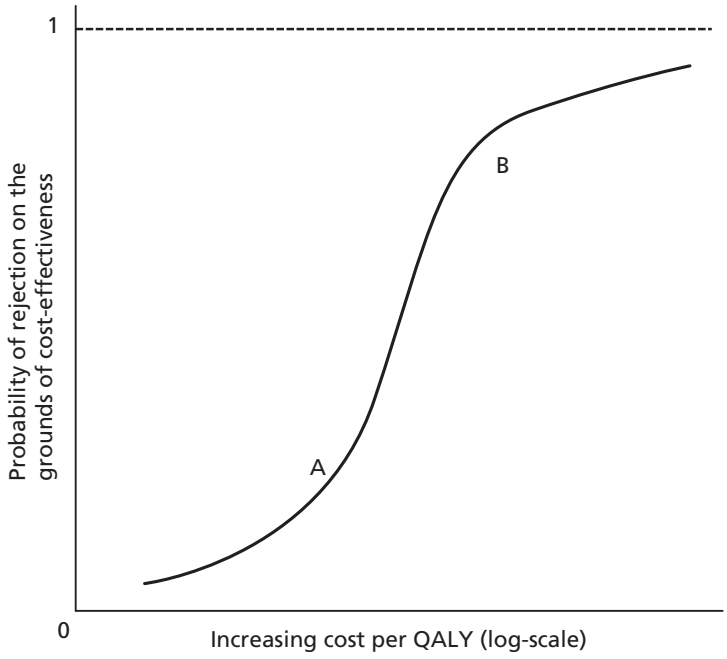


FIGURE 10 Probability of rejection with a 'soft' cost-effectiveness threshold. A and B represent the two points of infection.

McCabe *et al.*[2] and Devlin and Parkin[6]). This graph represents the probability of rejection of a new technology as a function of the technology's ICER. The graph clearly shows two points of inflection (A and B in *Figure 10*), these two points represent an interpretation of the lower and upper bounds of a cost-effectiveness threshold range.

The literature often makes use of the terms 'soft' and 'hard' when referring to the threshold. The term 'soft' is often used in a similar way to the threshold 'range' (alternatively Akehurst's 'smudge'[130]). Although the underlying idea is the same, a 'soft' threshold has also been used to refer to a single threshold. For example, McCabe *et al.*[2] argued that it is both feasible and probably desirable to use a single threshold rather than a range, as the threshold should represent the point beyond which factors other than cost-effectiveness are considered. This approach would suggest that all new technologies with an ICER below the threshold should receive funding (regardless of their impact on other factors such as equity of health). It is, however, unclear from this paper what the implications are for technologies with an ICER beyond the single threshold value.

In contrast, a 'hard' threshold represents the situation where the ICER valuation is the sole relevant variable in an adoption decision, as demonstrated in *Figure 11*.[119] It is an important point that if a 'hard' threshold is set, no other factors can be considered in the decision-maker's consideration of a new technology. The difference between a 'hard' and a 'soft' threshold is therefore largely based on whether or not the ICER reflects all considerations. Assuming the decision-maker is optimising health, a hard threshold should represent the most effective allocation of a health-care budget, but cannot account for any equity concerns (such as the severity of the condition, unmet need and orphan diseases) that are not included in the calculation of the ICER. Authors such as Dolan *et al.*[21] have demonstrated that a 'hard' threshold may not be able to suitably reflect the non-linearity of social or political values of QALYs to factors such as quality and length-of-life and for those with worse health prospects or dependents.

What does the threshold represent?

Two broad lines of thought have developed on what the threshold represents, social WTP and shadow pricing.[1,2,8,12,16,17] The key difference between the two is the budget that should be considered by those accepting or rejecting health technologies. The social WTP approach (usually implicitly) assumes that the budget of the health-care sector is flexible to the value of health gains determined by society. So in this case it is the value society places on the health benefits (e.g. in QALYs) generated by new health-care

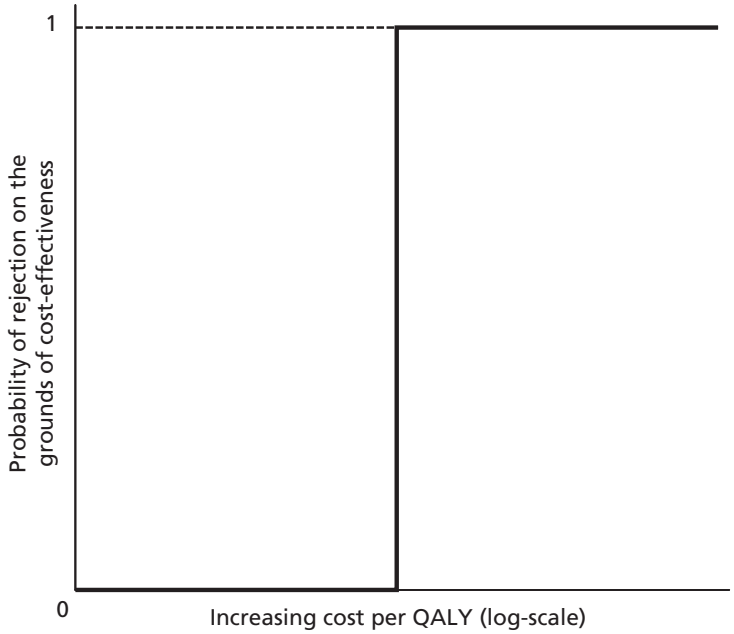


FIGURE 11 Graph showing a 'hard' cost-effectiveness threshold.

programmes and technologies is estimated first, and then the health-care budget is the sum of society's WTP for all treatments. In other words, the threshold is set exogenously with no reference to a budget constraint.

In contrast, the shadow pricing approach takes the budget as given (at least beyond the control of those who determine the cost-effectiveness threshold).[1,2] The threshold is, therefore, endogenously based on the services currently provided within the system. When a new programme or technology is accepted into the system and imposes an additional cost onto the budget, the only way to meet those costs is to remove or down-scale existing services which will incur *opportunity costs* in terms of population health. Hence the threshold represents the ICER of the least cost-effective *existing* service covered by the budget. In principle, it is this service which is removed to fund a new programme or technology. In practice, a range of criteria is likely to be used to identify appropriate services for displacement to make room in the budget for new interventions.

In the UK, the main source of debate about which of these concepts of the threshold is the correct one lies in NICE's remit. Authors such as Culyer *et al.*[1] have discussed NICE's position as a 'searcher' or a 'setter' of the threshold. The distinction between these two roles is that a threshold 'searcher' does not set a threshold with the motivation of maximising social welfare under the assumption of a flexible NHS budget, but instead investigates the threshold value that is appropriate given current NHS activities and the fixed budget as set down by Parliament.

Much of the literature on this topic is founded in the discussion of the correct constitutional role of NICE, the potential negative implications of setting a threshold and the feasibility of identifying displaced activities. In 2007, Culyer *et al.*[1] argued that it is not appropriate for NICE to be characterised as a threshold setter. The authors argued that the setting of a threshold would effectively imply that NICE sets the NHS budget. The setting of the NHS budget, they highlight, is the constitutional responsibility of Parliament, not NICE. Hence the paper argues that NICE should concern themselves with being threshold 'searchers', seeking to identify 'an optimal threshold ICER, at the ruling rate of expenditure, that is consistent with the aim of the health service to maximise population health' (p. 4).[1]

In a similar vein Appleby *et al.*[56] concluded that the threshold used by NICE should be consistent with the decisions made by local commissioners within the NHS. This is important given that NICE provides little guidance to the NHS regarding interventions suitable for disinvestment to release the funding necessary to cover the new technologies it recommends. If the threshold is set too high NICE may well accept new technologies which are less cost-effective than the services which local commissioners displace to fund those technologies. Conversely, if the threshold is set too low, NICE is likely to reject services that are cost-effective relative to existing services delivered from the NHS budget. The authors conclude that, in the short term, NICE have to act as a threshold 'searcher' to ensure continuity in the NHS.

Alternative arguments have been put forward which reject the idea of NICE as a threshold 'searcher'. First, some authors (such as Gafni and Birch[7,120]) have made the case that an implicit threshold has the potential to lead to spiralling inflation if new cost-effective technologies are funded without sufficient disinvestment. However, McCabe *et al.*[2] argued that Culyer's characterisation of the NICE threshold could overcome this challenge if it were regularly reviewed so as to be flexible over time to changes in the NHS budget and the productivity of the sector, and if the threshold for new activities with a non-marginal budget impact was greater than those with a marginal impact. The issue of the inflationary pressure of a threshold is discussed further below.

Another concern raised about Culyer *et al.*'s[1] characterisation of the NICE threshold is that of Towse.[48] They argue that a lack of knowledge of the true opportunity cost of new activities makes us unable to identify the value of those activities being displaced and, therefore, it is impossible for NICE to 'search' for a threshold relating to activities displaced at the margin. The issue of the difficulty of identifying current activities at the margin in terms of cost-effectiveness will be dealt with later in this chapter.

Factors considered by the National Institute for Health and Care Excellence other than the comparison of the incremental cost-effectiveness ratio and threshold

As was discussed in the section *The threshold as a range*, the suitable threshold approach is dependent on the policy context around it, specifically if the comparison of the ICER with the threshold represents the only relevant piece of information that informs an adoption decision (a 'hard' threshold) or if it is simply one of many factors considered ('soft' threshold). In the case of the UK, NICE has openly stated the ICER of a technology is not the sole consideration of the committee in its adoption decisions.[5]

Both NICE and a number of other authors have provided overviews of the other factors that are considered by NICE in the adoption decision, these are provided in *Table 35*.

Table 35 suggests that the threshold is only one consideration to decision-makers at NICE. However, in principle, these other types of benefits could be added to health benefits and compared with potential treatments for displacement which also have wider social benefits. In other words, this wider set of considerations relating to the benefits of new technologies should arguably also be reflected in the threshold.[a]

Multiple thresholds

Similarly, some have argued for using different thresholds for different situations.[2,17] The two main cases for using different thresholds are the size of the budgetary impact, or depending on whether the decision represents an investment in additional activities or a disinvestment in current activities.

The topic of different thresholds for different budgetary impacts of a proposed technology has received very little analytical attention from the literature. McCabe *et al.*[2] argue that technologies with a large budgetary impact should be evaluated against a lower threshold than those with a relatively small impact. The reason for this is a large budgetary impact will require a greater displacement of current activities (assuming a fixed overall budget); this may result in displacement of non-marginal activities which may be associated with a lower ICER than those at the margin.

Several authors have suggested the use of different threshold values depending on whether the decision represents an investment in additional activities or a disinvestment in current activities. O'Brien *et al.*'s 2002 paper[131] considers the difference in willingness to accept monetary compensation to

TABLE 35 Table showing factors other than ICER considered by NICE

NICE[3,5]	Rawlins *et al.*[39]	Tappenden *et al.*[40]	Devlin and Parkin[6]
Uncertainty of variables	Severity of illness	Uncertainty of the ICER	Uncertainty of the ICER
Availability of comparators	End-of-life treatment	Availability of comparators	Burden of disease
Clinical priorities (as set by Secretary of State)	Stakeholder opinion	Severity of illness	
Clinical need	Innovation		
Availability of resources	Population characteristics (disadvantaged and children)		
Innovation			
Disease characteristics and population size			
Wider social costs and benefits			
Length of benefit			

forgo a health-care programme and WTP for the same benefit and link it to the cost-effectiveness threshold. This paper came from the perspective of the threshold representing social preferences rather than the shadow price of a fixed budget constraint and highlights that from a traditional 'welfarist' economics standpoint; a greater threshold value for disinvestment may be welfare maximising. Similarly, both Devlin and Parkin[6] and Speight and Reaney[132] have suggested a threshold for disinvestment of currently performed activities could be lower than for new activities, however, neither present any methodology for calculating the weight of a disinvested activity.

This is in contrast with the view that CEA guides the decisions of health systems with the objective of maximising some measure of health benefit subject to a budget constraint. Hughes and Ferner[50] argued that differential thresholds with respect to investment and disinvestment would result in suboptimal levels of population health. This is because a new technology that would improve health may be rejected under a policy of having different thresholds for investment and disinvestment but not if the threshold values were the same. The authors argue that this failure to maximise population health represents an avoidable inefficiency not related to the aim of the health-care sector to maximise health and thus making the case for a single threshold value for disinvestment and investment. This point can be seen as a further case for the shadow price approach as opposed to the social WTP perspective as it highlights that, given a fixed NHS budget, the social WTP approach will not lead to a maximisation of health.

The need for an independent threshold panel

Related to the discussion over the correct role of NICE in determining a suitable cost-effectiveness threshold for the NHS is the literature on the potential for an independent threshold panel. Such a panel has been characterised in a similar manner to the Monetary Policy Committee (the setters of the Bank of England's interest rate who act independently of the Government of the UK), as an independent committee responsible for the setting and updating of the cost-effectiveness threshold used by NICE.

The papers covering this topic are consistent in their call for an independent threshold panel, with no papers identified arguing against it. The main case provided in the literature for an independent setter is the removal of political influence; Claxton *et al.*[99] argue that political influence may drive the threshold up as politicians seek to use the threshold as a means to encourage investment by pharmaceutical companies. Williams[8] suggests that NICE is biased in the setting of a threshold, as its political connections mean a higher threshold makes it more popular with the 'sellers' (the author defines sellers as not only the pharmaceutical industry but health-care professionals and patient groups) by allowing more technologies to be approved. Similarly, papers by Appleby *et al.*[56] and Raftery[133] call for the creation of an independent threshold setter. The 2008 Health Select Committee[14] recommended that a body independent of NICE should be established to set and review the threshold. However, it is unclear if such a body would also be independent of political influence or just of the NICE structure.

Arguments against the use of a cost-effectiveness threshold

A number of authors have argued against the use of a threshold. As mentioned earlier authors such as Gafni and Birch[7,120] have suggested that the threshold approach risks leading to spiralling increases in inflationary pressures on health-care spending, and present an alternative approach based on the use of league tables of cost-effectiveness. The reason, they argue, is that there is no guarantee that the activities displaced are less cost-effective than those new technologies imposing costs on the health system budget. This observation is coupled with the expectation of authors such as Cohen and Looney[118] that pharmaceutical firms will inevitably price their drugs so as to ensure the ICER of their proposed new technology is sufficiently close to the threshold to ensure adoption and thereby gain maximum producer surplus. This observation implies that providers such as the NHS may be forced to pay above market costs of new technologies by revealing their maximum WTP, in the form of the threshold. In addition the point raised in McCabe *et al.*[2] that the threshold should be adjusted regularly over time to ensure its efficiency seeks to address both of these arguments.

Other authors such as Eichler *et al.*[52] have raised and debated the issues around the theoretical base for the cost-effectiveness threshold, namely the assumption of perfect divisibility of health-care programmes, constant returns to scale and constant marginal opportunity costs.

Bridges *et al.*[119] argues that a unique threshold value imposes impractical assumptions in the case of the US health-care sector, and fails to account for supply and demand side variations in the market. As an alternative the authors propose a series of thresholds that reflect regional, dynamic budgeting and general methodological differences. They conclude that the case for abandoning a fixed threshold outweighs those for keeping one in the USA and that any threshold should vary across payer, over time, in the true budget impact of interventions and in the measurement of the effectiveness of interventions. This argument has clear links to the argument for shadow pricing of the threshold rather than the social WTP approach, as the shadow price approach is based on the view that the threshold is determined by budget and current efficiency which can be seen to differ over time and across payers. The unresolved issue here is the degree to which different subgroups (e.g. by region or budget) require different threshold values.

Identification of activities under the threshold

An important part of the literature is the discussion around the identification of activities with an ICER greater than the proposed threshold. The importance of this discussion stems from the requirement of new activities to displace current activities that are at the margin of what is cost-effective. If it is not possible to identify these activities separately from others then threshold analysis is methodologically flawed, as the funding of a new activity may impact on an activity with an ICER above the proposed threshold.

Most literature on this topic focuses on the importance of identifying activities to be displaced rather than the process and feasibility of doing so. For example, Hughes and Ferner[46] and McCabe *et al.*[2] highlight the implications of inconsistent displacement on geographic variations in health-care provision and that the lack of consistency in the displacement process undercuts the use of a single cost-effectiveness threshold for the evaluation of new technologies. Similarly, Buxton[51] suggests that, in order to fully appreciate the opportunity cost of the implementation of a new technology, we must have a clear knowledge of those activities displaced at the cost-effectiveness margin.

Few authors have sought to develop methods to identify the activities that should be displaced to free-up budget for new more cost-effective activities. Elshaug *et al.*[52] outlines a set of criteria for the identification of existing, potentially non-cost-effective practices which could then be further assessed to determine their cost-effectiveness using health technology assessment. The criteria suggested include factors such as new evidence on safety; efficacy or cost-effectiveness; geographic variation that have become apparent since technology adoption; heterogeneity in the clinical procedure; and technological development.

The current value of the threshold

As it became evident that decision-making bodies such as NICE are using (more or less explicit) cost-effectiveness thresholds, there has been a significant level of debate over its appropriate value.[6,8,38,39,45,48,51,56,130,134–137] In this section we will present three areas of the debate:

1. the lack of empirical basis to the current value
2. arguments over the value being generally too high or too low
3. if and how the threshold should change over time.

Lack of empirical basis to the current value

Since NICE made it clear that it uses an explicit threshold[5] there has been little hiding the lack of evidential justification behind the £20,000–30,000 range. Indeed the Health Select Committee[14] heard (during their enquiry into NICE in 2008) that the NICE threshold has no basis in hard science. Similarly, Appleby *et al.*[56] noted that 'the uncomfortable truth is that NICE's threshold has no basis in either theory or evidence'.

Similarly, the US value of $50,000 per QALY, which is often cited as the cost-effectiveness threshold relevant to resource allocation decisions in that country, is often attacked for its lack of empirical founding.[33,45,122,124] Some have suggested that the US figure is rooted in the cost-effectiveness of hospital renal dialysis,[122] although why this makes it suitable for use more generally is unclear.

The threshold changing over time

Another concern of current NICE practice is the apparent lack of change in the threshold value used since the body's inception. Many authors have argued that factors such as the NHS budget, price inflation, technological developments in the NHS and the discount rate applied to economic evaluations[35,122,125,126] have all changed since the first use of the cost-effectiveness threshold. As such, the threshold should have changed to reflect this fact. Braithwaite and Roberts[45] sought to demonstrate the impact of budget and technological growth on the optimal threshold. By creating a computer simulation of the US Medicare system, the authors were able to demonstrate the impact of these factors. Although there is no doubt in the literature that the NICE threshold should potentially change over time,[a] no papers have been identified which model the impact of any changes on the threshold.

Both Ubel *et al.*[136] and Raftery[133] discuss the principles behind the directional change the threshold should take over time. Ubel *et al.*[136] have argued that the optimal threshold value needs to fall over time assuming medical innovation continues at roughly its current rate. Raftery[133] has noted that, in real terms, the threshold has been falling since 1999 as, in order to stay constant in real terms, it should have increased given inflation (up 40% in the time period) and increased NHS spending (up 90%). The authors argue that this decline in the threshold should have been observed in the value used by NICE in decision-making. They describe the suggestion of a rise in the threshold being linked to the observed growth of the NHS budget over the last decade as 'audacious'.[133] It is unclear to what extent the authors disagree with this interpretation of NHS efficiency as a relevant factor affecting the optimal threshold.

Threshold value generally too high or low

The majority of the debate over the current use of the threshold in the UK (and elsewhere) has been centred on whether the current value is too low or too high. The papers that will be discussed in this section focus on the general discussion of necessary directional change in the value rather than the presentation of a specific value; the latter is discussed in more detail in the following section on the proposed values of the threshold in the literature.

Vernon *et al.*[137] presented an analysis of the implications of the threshold being above or below its optimum value in terms of signals to the companies involved in research and development of new medical products. The authors concluded that if the threshold is set too low (below the economic value of the health benefit) it will result in research and development investment levels that are too low relative to their economic value (at the margin). The reason for this lies in a lack of returns to investments for the pharmaceutical companies. However, in the isolated case of the threshold relevant to the NHS (a small proportion of the world pharmaceutical market), the impact of changes to the threshold on the international pharmaceutical market equilibrium is unknown but likely to be small.

Similarly, thresholds set too high (above the economic value of the health benefit) will result in inefficiently high levels of research and development spending, such that the health-care provider is funding projects that do not have a sufficient impact on social welfare.

The literature that argued the threshold is too high in the UK can be broadly characterised into three key papers. Williams[8] made the case that, intuitively, the threshold should not be significantly greater than the gross domestic product (GDP) per capita (roughly £18,000 in the UK in 2004). He made the case that, although it may be possible to provide a lot of the population with health care when the threshold is above the GDP per capita, it is not possible to provide health care for much of the population without imposing great hardship on those expected to foot the bill (the tax payer or government debt).

Second, Raftery[133] argued that, although the UK threshold has been historically too high, it does not need reducing as the real value has decreased since 1999 due to inflationary pressure and increases in the NHS budget. He also suggests that recent policies implemented by NICE, such as greater weight being given to the benefits of treatment accruing to patients at the end of their life, need to be offset by reductions in the threshold for all other treatments for expenditure to remain within the NHS budget. Finally, Raftery cites the opportunity cost analysis of trastuzumab (Herceptin®, Roche)[114] which showed that more cost-effective oncology services were being sacrificed to fund trastuzumab in breast cancer. This result suggests directly that, in some cases at least, the threshold value is too high.

Work by Martin *et al.*[57–59] investigated the cost per life-year saved in a selection of the 23 PBCs used in the NHS; these results are presented in *Table 36*. It is important to note that these results are presented as the cost per YLG rather than the cost per QALY of the least cost-effective current activity. The authors and others have used these results to argue that the threshold used by NICE may be too high.[128] Similarly, Collier's[47] report of the Health Select Committee suggests that the threshold used by NICE is higher than that used by PCTs.

In contrast, a range of authors have argued that the current NICE threshold is too low. Both Speight and Reany[132] and Towse[48] argued that the inclusion of wider social costs/benefits and full consideration of social WTP for additional health gains show that the threshold should be significantly larger. Both cite recent NICE work by Mason *et al.*[29,135] which suggested the threshold should be between £30,000 and £75,000 per QALY based on attempts to model a WTP-based value of a QALY based on observations of the value of avoiding a statistical fatality. Similarly, in the USA, Ubel *et al.*[136] have argued that, if inflation and WTP valuations are taken into account, the relevant threshold in the US should be closer to $200,000 per QALY than the regularly cited $50,000.

Those analyses which conclude the UK and US thresholds should be significantly higher have, at the core of their argument, the assumption that the respective health-care budget is fully capable of responding to society's WTP for additional health gains.

Potential methods for threshold estimation

There are broadly three approaches that can be taken to determine the threshold value:[51,56] social WTP, non-analytical approaches. Such as expert elicitation and shadow pricing of the budget constraint. This project is concerned with the latter approach to estimating the cost-effectiveness threshold. This is entirely consistent with the remit of the NHS in general and NICE in particular – they do not set the NHS budget but have to allocate those finite resources appropriately.

TABLE 36 Table showing cost per YLG results of Martin *et al.* papers[57–59]

	Cost per YLG (£)	
PBC	2005/6 data	2004/5 data
Cancer	13,137	13,931
Circulation problems	8426	7979
Respiratory problems	7397	N/A
Gastrointestinal problems	18,999	N/A
Diabetes	26,453	N/A

N/A, not applicable.

Papers seeking to elicit social willingness to pay and non-analytical approaches

The majority of the literature that has presented a proposed value for the threshold (in the UK, USA and elsewhere) has done so using valuation methods based on WTP for an additional health benefit.[18–32,34–37] However, other approaches have been suggested. For example, the WHO's 2002 report[138] suggested that interventions costing less than three times GDP per capita for each DALY averted represent good value for money.

Lee *et al.*[139] sought to update the US 'dialysis standard' often claimed to be the base of the US Medicare threshold.[122] The authors present a valuation of $129,090 per QALY based on current dialysis practice in the USA. Finally, in an appendix to their edited book, Towse *et al.*[130] provide an interesting set of results drawn from a set of participants to the associated workshop (the majority of which were health economists). The participants were asked to anonymously record their view on what threshold NICE should apply. Eighteen responses were recorded with the average of all responses being £29,000 per QALY.

Papers considering the shadow price of the budget constraint

The systematic review only identified four different papers by three different authors that suitably fell into the category of shadow pricing of the budget constraint.

Williams[8] suggested investigating the cost-effectiveness of NHS interventions that represent the majority of the budget (he speculated that some 300 interventions accounted for about 90% of the cost incurred by the NHS). The purpose of this would be to identify current NHS activities that might not be cost-effective. He acknowledged the implausibility of conducting full technological appraisals on such a large number of interventions (estimating this would take 10 years, at which point it would be necessary to re-evaluate the initial appraisals), and thus suggested relying on expert opinion and existing patient data to speed up the process.

While Williams' recommendations related to identifying current interventions with a high cost per QALY as the basis for disinvestment, there is the potential to take this approach further and use it for a method to determine the cost-effectiveness threshold even down to the level of a local decision-maker. This was attempted by Appleby *et al.*[49] who conducted a feasibility experiment into the estimation of the appropriate NHS threshold by examining decision-making in the NHS at a local level. The authors propose a structured model considering the new technology's cost per weighted QALY gain in a table of all existing services. In an attempt to test the feasibility of this model they conducted interviews with senior NHS staff as well as investigating information on public health to construct a list of health-care services introduced or discontinued in 2006/7. The authors found that it was feasible to identify decisions and to make the important step of estimating their cost-effectiveness; however, they noted that any attempts to fully evaluate sufficient decisions as to estimate a threshold would require a detailed understanding of the decision structure at a local level as well as a significant number of observations.

The other key papers seeking to develop and implement methods for estimating the NHS threshold were those of Martin *et al.*[57–59] They aimed to establish a link between health-care spending and health outcomes in the NHS after having adjusted for the need of the patient population. They made use of data around the observed mortality at PCT level in the NHS alongside expenditure data on health care across 23 programmes of care based on ICD-10 disease categories. As has been mentioned earlier in this chapter these papers present the cost per life-year for a range of PBCs; however, the key result of these papers is that it is possible to make use of existing data to determine such valuations for current NHS interventions. The authors concluded that although their results are highly limited and do not present a single cost per QALY estimate for the optimal threshold they can 'inform the decisions of NICE on whether their current threshold for accepting new technologies is set at an appropriate level' (p. 37). These studies are the precursor of analyses presented in this report, and further details can be found in *Appendix 2* and in *Chapter 3* of the main report.

In the area of the efficient allocation of health care it is also important to note the contribution of the earlier mathematical papers such as Stinnett and Paltiel[16] who outlined mathematical techniques to approach the problem through the use of a mixed integer programming approach. Although their approach differs from the interpretation of the threshold as used in this study it represented an important step in the evaluation of the methodology of seeking to solve the optimisation problem apparent in health care.

Conclusion

This systematic review of the literature surrounding the cost-effectiveness threshold has highlighted the significant range and diversity of the literature. Despite the international and mature nature of the literature there are significant differences in the suggested methods to represent a cost-effectiveness threshold. The main areas of debate relevant to this report have revolved around the role of NICE as a 'searcher' or 'setter' of the threshold.[1,2] Although some authors have implicitly argued for NICE to fulfil the role of a threshold 'setter' by suggesting methods of elicitation of social WTP valuations of a QALY, death or life-year,[18–32,34–37] the literature of most relevance to this research has sought to consider estimation methods consistent with its role as a 'searcher'.[56–59]

Papers discovered by the literature review

Note: not all of these papers are referenced in this appendix and some references used were not discovered through the systematic review.

Initial pearls

Appleby J, Devlin N, Parkin D. NICE's cost effectiveness threshold – how high should it be? *BMJ* 2007;**335**:358–9.

Appleby J, Devlin N, Parkin D, Buxton M, Chalkidou K. Searching for cost effectiveness thresholds in the NHS. *Health Policy* 2009;**91**:239–45.

Bridges JFP, Onukwugha E, Mullins CD. Healthcare rationing by proxy cost-effectiveness analysis and the misuse of the $50 000 threshold in the US. *Pharmacoeconomics* 2010;**28**:175–84.

Culyer A, McCabe C, Briggs A, Claxton K, Buxton M, Akehurst R, *et al.* Searching for a threshold, not setting one: the role of the National Institute for Health and Care Excellence. *J Health Serv Res Policy* 2007;**12**:56–8.

Devlin N, Parkin D. Does NICE have a cost-effectiveness threshold and what other factors influence its decisions? A binary choice analysis. *Health Econ* 2004;**13**:437–52.

Gafni A, Birch S. Incremental cost-effectiveness ratios (ICERs): the silence of the lambda. *Soc Sci Med* 2006;**62**:2091–100.

McCabe C, Claxton K, Culyer AJ. The NICE cost-effectiveness threshold – what it is and what that means. *Pharmacoeconomics* 2008;**26**:733–44.

Raftery J. Should NICE's threshold range for cost per QALY be raised? No. *BMJ* 2009;**338**:268–9.

Towse A. Should NICE's threshold range for cost per QALY be raised? Yes. *BMJ* 2009;**338**:268–9.

Braithwaite RS, Meltzer DO, King JT Jr, Leslie D, Roberts MS. What does the value of modern medicine say about the $50,000 per quality-adjusted life-year decision rule? *Med Care* 2008;**46**:349–56.

Grosse S. Assessing cost-effectiveness in healthcare: history of the $50,000 per QALY threshold. *Exp Rev Pharmacoecon Outcomes Res* 2008;**8**:165–78.

Rawlins MD, Culyer AJ. National Institute for Clinical Excellence and its value judgments. *BMJ* 2004;**329**:224–7.

Chambers JD, Neumann PJ, Buxton MJ. Does Medicare have an implicit cost-effectiveness threshold? *Med Decis Making* 2010;**30**:E14–27.

Step 1 results

Brouwer W, can Exel J, Baker R, Donaldson C. The new myth – the social value of the QALY. *Pharmacoeconomics* 2008;**26**:1–4.

Claxton K, Lindsay AB, Buxton MJ, Culyer AJ, McCabe C, Walker S, *et al*. Value based pricing for NHS drugs: an opportunity not to be missed? *BMJ* 2008;**336**:251–4.

Cohen J, Looney W. Re: How much Is life worth: cetuximab, non-small cell lung cancer, and the $440 billion question. *J Natl Cancer Inst* 2010;**102**:1044–8.

Eichler HG, Kong SX, Gerth WC, Mavros P, Jonsson B. Use of cost-effectiveness analysis in health-care resource allocation decision-making: how are cost-effectiveness thresholds expected to emerge? *Value Health* 2004;**7**:518–28.

Green C, Gerard K. Exploring the social value of health-care interventions: a stated preference discrete choice experiment. *Health Econ* 2009;**18**:951–76.

Groot W, van den Brink HM. The value of health. *BMC Health Serv Res* 2008;**8**:136.

Hughes DA, Ferner RE. New drugs for old: disinvestment and NICE. *BMJ* 2010;**340**:690–2.

Lieu TA, Ray G, Ortega-Sanchez I, Kleinman K, Rusinak D, Prosser L. Willingness to pay for a QALY based on community member and patient preferences for temporary health states associated with herpes zoster. *Pharmacoeconomics* 2009;**27**:1005–16.

Mason AR, Drummond MF. Public funding of new cancer drugs: is NICE getting nastier? *Eur J Cancer* 2009;**45**:1188–92.

Mason H, Jones-Lee M, Donaldson C. Modelling the monetary value of a qaly: a new approach based on UK data. *Health Econ* 2009;**18**:933–50.

Maynard A, Bloor K. The future role of NICE. *BMJ* 2010;**341**:c6286.

Rascati KL. The $64,000 question – what is a quality-adjusted life-year worth? *Clin Ther* 2006;**28**:1042–3.

Rawlins M, Barnett D, Stevens A. Pharmacoeconomics: NICE's approach to decision-making. *Br J Clin Pharmacol* 2010;**70**:346–9.

Shiroiwa T, Sung YK, Fukuda T, Lang HC, Bae SC, Tsutani K. International survey on willingness-to-pay (WTP) for one additional QALY gained: what is the threshold of cost effectiveness? *Health Econ* 2010;**19**:422–37.

Speight J, Reaney M. Wouldn't it be NICE to consider patients' views when rationing health care? *BMJ* 2009;**338**:297.

Tappenden P, Brazier J, Ratcliffe J, Chilcott J. A stated preference binary choice experiment to explore NICE decision making. *Pharmacoeconomics* 2007;**25**:685–93.

Weinstein MC. How much are Americans willing to pay for a quality-adjusted life-year? *Med Care* 2008;**46**:343–45.

Yaesoubi R, Roberts SD. A game-theoretic framework for estimating a health purchaser's willingness-to-pay for health and for expansion. *Health Care Manag Sci* 2010;**13**:358–77.

Step 2 results

Appleby J, Devlin N, Parkin D, Buxton M, Chalkidou K. *Searching for Local NHS Cost Effectiveness Thresholds: A Feasibility Study*. NICE Conference Manchester. 5–6 December 2007. URL: www.nice2007.co.uk/ApplebyDevlin.pdf (accessed 12 January 2012).

Birch S, Gafni A. The biggest bang for the buck or bigger bucks for the bang: the fallacy of the cost-effectiveness threshold. *J Health Serv Res Policy* 2006;**11**:46–51.

Braithwaite RS, Roberts MS. *$50,000 per QALY: Inertia, Indifference, or Irrationality?* Presented at the Annual Meeting of the Society for Medical Decision Making. Atlanta, GA, USA, 17–20 October, 2004.

Drummond M, Torrance G, Mason J. Cost-effectiveness league tables: more harm than good? *Soc Sci Med* 1993;**37**:33–40.

Gerard K, Mooney G. QALY league tables: handle with care. *Health Econ* 1993;**2**:59–64.

Gyrd-Hansen D. Willingness to pay for a QALY: theoretical and methodological issues. *Pharmacoeconomics* 2005;**23**:423–32.

Hammitt JK. The $64,000 question: what are we willing to pay for a QALY. *ISPOR Connect* 2005;**11**:7–9.

Hirth RA, Chernew ME, Miller E, Fenderick AM, Weissert WG. Willingness to pay for a quality-adjusted life-year: in search of a standard. *Med Decis Making* 2000;**20**:332–42.

King JT Jr, Tsevat J, Lave JR, Roberts MS. Willingness to pay for a quality-adjusted life-year: implications for societal health care resource allocation. *Med Decis Making* 2005;**25**:667–77.

Lee C, Chertow G, Zenios S. An empiric estimate of the value of life: updating the renal dialysis cost-effectiveness standard. *Value Health* 2009;**12**:80–7

Martin S, Rice N, Smith P. *Further Evidence on the Link Between Health Care Spending and Health Outcomes in England* [CHE 28. National Institute for Health and Care Excellence. NICE discussion paper 32]. York: University of York; 2007.

Martin S, Rice N, Smith PC. *The Link Between Health Care Spending and Health Outcomes for the New English Primary Care Trusts.* CHE Research Paper 42. York: University of York; 2008.

Mauskopf J, Rutten F, Schonfeld W. Cost-effectiveness league tables: valuable guidance for decision makers? *Pharmacoeconomics* 2003;**21**:991–1000.

Smith RD, Richardson J. Can we estimate the 'social' value of a QALY? Four core issues to resolve. *Health Policy* 2005;**74**:77–84.

Stinnett AA, Paltiel AD. Mathematical programming for the efficient allocation of health care resources. *J Health Econ* 1996;**15**:641–53.

Towse A, Pritchard C, Devlin N, eds. *Cost Effectiveness Thresholds: Economic and Ethical issues*. London: Office of Health Economics, The King's Fund; 2002.

Ubel PA, Hirth RA, Chernew ME, Fendrick AM. What is the price of life and why doesn't it increase at the rate of inflation? *Arch Int Med* 2002;**163**:1637–41.

Williams A. *What Could Be Nicer Than NICE?* London: Office for Health Economics; 2004.

Winkelymayer WC, Weinstein MC, Mittelman MA, Glynn RJ, Pliskin JS. Health economic evaluations: the special case of end-stage renal disease treatment. *Med Decis Making* 2002;**22**:417–30.

Step 3 results

Baker R, Bateman I, Donaldson C, Jones-Lee M, Lancsar E, Loomes G, *et al.* Weighting and valuing quality-adjusted life-years using stated preference methods: preliminary results from the Social Value of a QALY Project. *Health Technol Assess* 2010:**14**(27).

Bobinac A, van Exel N, Rutten FFN, Werner B. Willingness to pay for a quality-adjusted life-year: the individual perspective. *Value Health* 2010;**13**:1046–55.

Brock DW. How much is more life worth? *Hastings Center Rep* 2006;**36**:17–19.

Byrne MM, O'Malley K, Suarez-Almazor ME. Willingness to pay per quality-adjusted life-year in a study of knee osteoarthritis. *Med Decis Making* 2005;**25**:655–66.

Griffin S, Claxton K, Sculpher M. Decision analysis for resource allocation in health care. *J Health Serv Res Policy* 2008;**13**:23–30.

Gyrd-Hansen D. Willingness to pay for a QALY. *Health Econ* 2003;**12**:1049–60.

Harrison S. A policy agenda for health-care rationing. *Br Med Bull* 1995;**51**:885–99.

Laufer F. Thresholds in cost-effectiveness analysis – more of the story. *Value Health* 2005;**8**:86–7.

Pinto-Prades JL, Loomes G, Brey R. Trying to estimate a monetary value for the QALY. *J Health Econ* 2009;**28**:553–62.

Vernon JA, Goldberg R, Golec J. Economic evaluation and cost-effectiveness thresholds signals to firms and implications for R&D investment and innovation. *Pharmacoeconomics* 2009;**27**:797–806.

Step 4 results

Abelson P. The value of life and health for public policy. *Econ Record* 2003;**79**:S2–13.

Fryback DG, Lawrence WF. Dollars may not buy as many QALYs as we think: a problem with defining quality-of-life adjustments. *Med Decis Making* 1997;**17**:276–84.

Gafni A, Birch S. Guidelines for the adoption of new technologies – a prescription for uncontrolled growth in expenditures and how to avoid the problem. *CMAJ* 1993;**148**:913–17.

Johnson FR. Einstein on willingness to pay per QALY: is there a better way? *Med Decis Making* 2005;**25**:607–8.

Laupacis A, Feeny D, Detsky A, Tugwell P. How attractive does a new technology have to be to warrant adoption and utilization – tentative guidelines for using clinical and economic evaluations. *CMAJ* 1992;**146**:473–81.

Polsky D. Does willingness to pay per quality-adjusted life-year bring us closer to a useful decision rule for cost-effectiveness analysis? *Med Decis Making* 2005;**25**:605–6.

Martin S, Rice N, Smith P. *The Link Between Health Care Spending and Health Outcomes: Evidence from English Programme Budgeting Data*. *CHE Research Paper 24*. York: Centre for Health Economics; 2007.

Chambers JD, Neumann PJ, Buxton MJ. Does Medicare have an implicit cost-effectiveness threshold? *Med Decis Making* 2010;**30**:E14–27.

Step 5 results

Birch S, Gafni A. Cost-effectiveness ratios – in a league of their own. *Health Policy* 1994;**28**:133–41.

Johnson FR, Backhouse M. Eliciting stated preferences for health-technology adoption criteria using paired comparisons and recommendation judgments. *Value Health* 2006;**9**:303–11.

Step 6 results

Dolan P, Shaw R, Tsuchiya A, Williams A. QALY maximisation and people's preferences: a methodological review of the literature. *Health Econ* 2004;**14**:197–208.

Baker R, Bateman I, Donaldson C, Jones-Lee M, Lancsar E, Loomes G, *et al.* Weighting and valuing quality-adjusted life-years using stated preference methods: preliminary results from the Social Value of a QALY Project. *Health Technol Assess* 2010;**14**(27).

O'Brien BJ, Gertsen K, Willan A, Faulkner L. Is there a kink in consumers' threshold value for cost-effectiveness in health care? *Health Econ* 2002;**11**:175–80.

Buxton M. How much are health-care systems prepared to pay to produce a QALY? *Eur J Health Econ* 2005;**6**:285–7.

Mason AR, Drummond MF. Public funding of new cancer drugs: is NICE getting nastier? *Eur J Cancer* 2009;**45**:1188–92.

Appendix 2 The link between NHS spending and mortality: estimating the cost of a life-year in England[a]

Prologue

This report presents, in a linear fashion, details of the econometric work undertaken to estimate the link between NHS spending and mortality. It also presents details of how the econometric work is used to calculate the cost of a life-year. This report is designed to serve as a reference document in support of the main project report, which highlights the major findings from the project. As a supporting document this report provides far more detail than most interested parties will require. Nevertheless, those who seek more detail than that contained in the main project report may find the material here useful.

Background, model, data, and estimation approach

Introduction

In a recent White Paper the new British Conservative government emphasised the importance of clinical outcomes. It notes that, in future, success will be measured, not through the achievement of process targets, such as short waiting times, but against outcomes such as cancer and stroke survival rates.[12] Although the NHS budget is ring-fenced against the ongoing public sector deficit reduction programme, its budget is still likely to be under considerable pressure, and attention is likely to focus on the extent to which any additional health-care expenditure yields genuine patient benefits in the form of improved health outcomes.

However, one of the most fundamental yet unresolved issues in health policy is the extent to which additional health-care expenditure yields patient benefits, in the form of improved health outcomes. The work of health technology agencies, such as NICE, has greatly improved our understanding at the micro-level of the costs and benefits of individual therapeutic technologies. However, there remains a dearth of evidence at the macro-level on the benefits of increased health system expenditure.

Recently a series of studies has taken advantage of the availability of two new data sets to examine the relationship between NHS expenditure and mortality rates for various disease categories.[59,60,62,63] One data set contains mortality rates for various disease categories at the level of geographically defined local health authorities, known as PCTs. The other data set presents NHS expenditure by PCT on 23 broad programmes of care. This data set embraces most items of publicly-funded expenditure, including inpatient, outpatient and community care, and pharmaceutical prescriptions.

Like previous studies, we employ a model that assumes that each PCT receives an annual financial lump sum budget from the national ministry and allocates its resources across the 23 programmes of care to maximize the health benefits associated with that expenditure. Estimation of this model using the expenditure and mortality data facilitates two related studies: first, a study of how changes in the NHS budget impact on expenditure in each care programme; and second, a study of the link between expenditure in a programme and the health outcomes achieved, notably in the form of disease-specific mortality rates. The latter study also permits the calculation of the cost of an additional life-year for individual programmes of expenditure.

The work presented here draws heavily on previous studies. These were constrained in a number of ways and, in this analysis, we build on and improve these previous studies in four major ways:

- First, due to data limitations previous studies related expenditure in time period t to mortality in periods t, $t-1$, and $t-2$ combined. In doing this, such studies assumed that PCTs had reached some sort of equilibrium in the expenditure choices they make and the outcomes they secure. This is probably not an unreasonable assumption given the relatively slow pace at which both types of variable change but, with more recent mortality data now available, here we relate expenditure in time period t to mortality in periods t, $t+1$, and $t+2$ combined (see *Model estimation using 2006/7 expenditure data and mortality data for 2006/7/8: CARAN need and two market forces factors*).
- Second, previous studies have tended to focus on a very limited number of care programmes (e.g. cancer, circulatory disease, gastrointestinal problems and respiratory problems). Here we present plausible outcome models for a larger number of budgeting categories.
- Third, previous estimates of the cost of a life-year have been for individual programmes of care. Here we present estimates of the cost of a life-year for an enlarged number of programmes and, importantly, with the aid of assumptions about the productivity of programmes without a meaningful mortality-based outcome indicator, we extend our individual programme estimates to incorporate expenditure across all programmes of care.
- Finally, although previous results and our current models 'pass' the appropriate statistical tests, we subject our latest results to a substantial sensitivity analysis.

The structure of this report is as follows. *Previous studies* presents a brief review of previous empirical studies in this domain, which have often yielded conflicting results. A straightforward theoretical model of the budgetary problem faced by a PCT manager seeking to allocate limited funds between competing programmes of care is presented in *Theoretical model*. The PB and health outcome (mortality) data are described in *NHS programme budgeting in England* and *Health outcome and other data* respectively. *Estimation issues and strategy* outlines our estimation methods and some of the issues surrounding them.

In *Analysis of programme budgeting expenditure for 2005/6 and mortality data for 2002/3/4* we commence our empirical work by estimating well-specified econometric models that outline (a) the budgetary expenditure choices and (b) the health outcomes achieved by PCTs using expenditure data for 2005/6 and mortality data for 2002/3/4. *Analysis of programme budgeting expenditure for 2006/7* presents results using expenditure data for 2006/7 and mortality data for 2004/5/6. It also presents results using the same expenditure data but updating the mortality data to 2006/7/8. Several pieces of sensitivity analysis are also included in *Analysis of programme budgeting expenditure for 2006/7*, but the major piece of sensitivity analysis – examining the impact of relaxing the instrument validity restriction – is reported in *The sensitivity of the outcome elasticity to the validity of the instrument exclusion restrictions*.

In *Analysis of programme budgeting expenditure for 2007/8 and mortality data for 2007/8/9* we re-estimate our model using updated expenditure and mortality data. In particular, we use the PB expenditure for 2007/8 and mortality data for 2007/8/9 to re-estimate our outcome and expenditure equations. In *Analysis of programme budgeting expenditure for 2008/9 and mortality data for 2008/9/10* we update the data set again, and this time we employ PB expenditure data for 2008/9 and mortality data for 2008/9/10. We also compare the elasticities and cost of a life-year estimates that we have obtained using expenditure and mortality data for different years.

Finally, *Summary and concluding remarks* presents a summary of our findings and some concluding remarks.

Previous studies

There is a large body of literature on the determinants of international variations in health-care spending in which income levels often play a central role.[140] However, whether or not more expenditure generates better outcomes – for example, in terms of reduced mortality – remains a matter of debate. For example, Fisher and Welch[141] note various ways in which more health care might harm patients and they cite various

studies supporting their arguments. In a comprehensive review, Nolte and McKee[67] discuss many studies that examine the impact of health care and other explanatory variables on some measure of health-care outcome. Nolte and McKee[67] point out that researchers usually combine a production function approach with the application of regression analysis. For example, in an early cross-sectional study of 18 developed countries, Cochrane *et al.*[64] use regression analysis to examine the statistical relationship between mortality rates on the one hand and per capita GNP and per capita consumption of inputs such as health-care provision on the other. They find that the indicators of health-care provision were generally not associated with the outcomes in the form of mortality rates. Thereafter, the failure to identify strong and consistent relationships between health-care expenditure and health outcomes (after controlling for other factors) has become a consistent theme in the literature, while, in contrast, socioeconomic factors are often found to be good determinants of health outcomes.[65–67]

This failure to detect a significant positive relationship between expenditure and health outcome might reflect the difficulties associated with any such study rather than the absence of such a relationship. For example, Gravelle and Backhouse[68] examine some of the methodological difficulties associated with empirical investigation of the determinants of mortality rates. These include simultaneous equation bias and the associated endogeneity problem (that the level of health-care input might reflect the level of health outcome achieved in the past), and that a lag may occur between expenditure and outcomes (studies typically assume that expenditure has an immediate effect on mortality). To avoid the difficulties imposed by data heterogeneity inherent in international analyses, the study by Cremieux *et al.*[69] examines the relationship between expenditure and outcomes across 10 Canadian provinces over the 15-year period 1978–92. They find that lower health-care spending is associated with a significant increase in infant mortality and a decrease in LE.

Although challenging the received empirical wisdom, one difficulty with the Cremieux *et al.*[69] study is that the estimated regression equation consists of a mixture of potentially endogenous variables (such as the number of physicians, health spending, alcohol and tobacco consumption, and expenditure on meat and fat) and exogenous variables (such as income and population density). The authors' chosen estimation technique (GLS) does not allow for this endogeneity and consequently the coefficients on the endogenous variables may be biased.[68] Or's[142] study of the determinants of variations in mortality rates across 21 Organisation for Economic Co-operation and Development countries between 1970 and 1995 may suffer from the same weakness. She finds that the contribution of the number of doctors to reducing mortality in Organisation for Economic Co-operation and Development countries is substantial but her estimation technique assumes that the number of doctors is exogenous to the health system.

Nixon and Ulmann[70] provide a detailed review of 16 studies that have examined the relationship between health-care inputs and health outcomes, using macro-level data. They also undertake their own study using data for 15 EU countries over the period 1980–95. They employ three health outcome measures – LE at birth for males and females, and the infant mortality rate – and a dozen or more explanatory variables including per capita health expenditure; number of physicians (per 10,000 head of population); number of hospital beds (per 1000 head of population); the average length of stay in hospital; the inpatient admission rate; alcohol and tobacco consumption; nutritional characteristics; and environmental pollution indicators. Nixon and Ulmann[70] conclude that although health expenditure and the number of physicians have made a significant contribution to improvements in infant mortality, '. . . health care expenditure has made a relatively marginal contribution to the improvements in LE in the EU countries over the period of the analysis'. Again, however, the study does not allow for the possibility that some of the explanatory variables may be endogenous.

Although loosely based on the notion of a health production function, the traditional empirical study described above has rarely been informed by an explicit theoretical model. This is understandable, as the processes giving rise to the observed health outcomes are likely to be very complex, and any theoretical model might become rather unwieldy. However, this absence of a model has usually led to a theoretical search for measures of health inputs demonstrating a statistically 'significant' association with health

outcomes. In contrast, in this study we inform our empirical modelling with a theoretical framework. We believe that this may lead to a more convincing and better specified model of health outcomes than that used in many previous studies, and this model is outlined in the next section.

Theoretical model

Our modelling framework assumes that each PCT i receives an annual financial lump sum budget y_i from the national ministry, and that annual total expenditure cannot exceed this amount. The PCT must then decide how to allocate its budget across the J programmes of care ($J = 23$ in this case). For each programme of care there is a 'health production function' $f_i(.)$ that indicates the link between local spending x_{ij} on programme j and health outcomes in that programme h_{ij}. Health outcomes might be measured in a variety of ways, but the most obvious is to consider some measure of improvement in LE, possibly adjusted for QoL, in the form of a QALY.

The nature of the specific health production function confronted by a PCT will depend on two types of local factors: the clinical needs of the local population relevant to the programme of care (which we denote n_{ij}); and broader local environmental factors z_{ij} relevant to delivering the programme of care (such as input prices, geographical factors, or other uncontrollable influences on outcomes). Both clinical and environmental factors may be multidimensional in nature. Increased expenditure then yields improvements in health outcomes, as expressed, for example, in improved local mortality rates, but at a diminishing rate. That is:

$$h_{ij} = f_j(x_{ij}, n_{ij}, z_{ij}); \delta f_j/\delta x > 0; \delta^2 f_j/\delta x^2 < 0. \tag{9}$$

We assume there is a PCT social welfare function $W(.)$ that embodies health outcomes across the J programmes of care. Assuming no interaction between programmes of care, each PCT allocates its budget so as to maximise total welfare, subject to the local budget constraint and the health production function for each programme of care:

$$\begin{aligned} &\max && W(h_{i1}, h_{i2}, \ldots, h_{iJ}) \\ &\text{subject to} && \sum_j x_{ij} \le y_i \\ & && h_{ij} = f_j(x_{ij}, n_{ij}, z_{ij});\ \ j = 1, \ldots J. \end{aligned} \tag{10}$$

It can of course quite plausibly be argued that decision-makers do not discriminate between health outcomes in different programmes of care, and that $W(.)$ is merely the sum of such outcomes. However, there is no need for that assumption in our formulation.

Each PCT allocates expenditure across the 23 programmes of care so that the marginal benefit of the last pound spent in each programme of care is the same. This is represented diagrammatically in *Figure 12*, which illustrates the trade-off between just two programmes of care. The top left-hand quadrant indicates the health production function for programme 1, whereas the bottom right-hand quadrant indicates the health production function for programme 2, albeit in transposed form. The bottom left-hand quadrant indicates the budget constraint; the expenditure choice must lie on the budget line. This means that for each feasible pair of expenditure choices (points on the budget constraint line), a pair of health outcomes in the two programmes emerges, which is traced out as the health production possibility frontier in the top-right quadrant. The PCT will choose the point on this frontier that maximizes welfare. In this example, we have indicated a simple health maximizing approach (the maximum health summing across the two programmes), leading to optimal health outcomes (H_1^*, H_2^*) and expenditure (X_1^*, X_2^*).

Solving the constrained maximisation problem yields the result that the optimal level of expenditure in each category, x_{ij}^*, is a function of the need for health care in each category (n_{i1}, n_{i2}, . . . , n_{ij}),

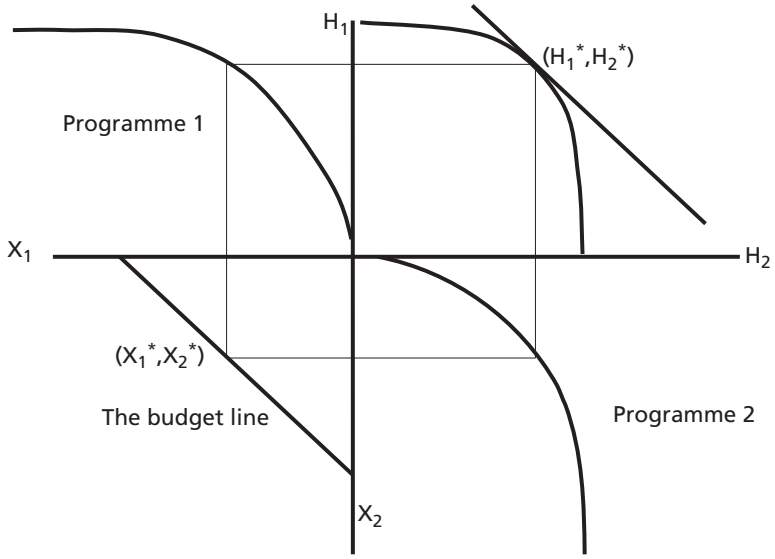


FIGURE 12 Graph showing optimal trade-off between two programmes of care.

environmental variables affecting the production of health outcomes in each category (z_{i1}, z_{i2}, . . ., z_{iJ}), and PCT income (y_i). Thus:

$$x_{ij}^{*} = g_j(n_{i1}, \ldots n_{iJ}, z_{i1}, \ldots z_{iJ}, y_i); \quad j = 1, \ldots, J \tag{11}$$

Thus, for each programme of care there exists an expenditure equation (see *Equation 11*) explaining expenditure choice of PCTs and a health outcome equation (see *Equation 9*) that models the associated health outcomes achieved.

Our model is static in the sense that the health production function (see *Equation 9*) assumes that all health benefits occur contemporaneously with expenditure. We acknowledge that for some programmes of care benefits might occur ≥ 1 year after expenditure has occurred. This is particularly likely to be the case for those programmes aimed at encouraging healthy lifestyles, where some benefits may occur decades after the actual programme expenditure. For other programmes, such as maternity/reproductive conditions and neonate conditions, benefits may be largely contemporaneous with expenditure. Furthermore, we do not model the decision-maker's time preferences.

For our empirical modelling, however, we are constrained by the data we have available, which are largely cross-sectional in nature. Owing to data limitations, previous studies have had to relate expenditure in period t to mortality data in periods t, $t-1$, and $t-2$ combined so that the mortality data precedes the expenditure data. This is not ideal. Implicitly previous studies have had to assume that the data represent a quasi long-run equilibrium position, and that relative expenditure levels and health outcomes within each PCT have been reasonably stable over a period of time. As we shall see, this appears to be a reasonable assumption because we obtain similar results when we estimate our models using expenditure for period t with either mortality data for periods t, $t-1$, and $t-2$ combined (see *Model estimation using 2006/7 expenditure data and mortality data for 2004/5/6: CARAN need and two market forces factors*) or with mortality data for periods t, $t+1$, and $t+2$ combined (see *Health outcome and other data*).

Having outlined our model, in the next section we discuss the data sets used to estimate this model.

NHS programme budgeting in England

The English NHS is the archetypal centrally-planned and publicly-funded health-care system. Its revenue derives almost entirely from national taxation, and access to the system is generally free to the patient.

Primary care is an important element of the system, and GPs act as gatekeepers to secondary care and pharmaceuticals. The system is organised geographically, with responsibility for the local administration of the NHS devolved to local health authorities known as PCTs.[b] For the purposes of this study, there were 303 PCTs with an average population of about 160,000 people until October 2006. In October 2006 the 303 PCTs became 152 PCTs. Some PCT boundaries remained unchanged whereas other PCTs were merged with one or more neighbours to form a new larger PCT. In a few cases the geographic area covered by an existing PCT was split between two or more new PCTs. These 152 PCTs have an average population of about 330,000 people.[c] PCTs are allocated fixed annual budgets by the national ministry, within which they are expected to meet expenditure on most aspects of health care, including inpatient, outpatient and community care, primary care and pharmaceutical prescriptions.

The rationale behind the construction of programme budget data

Traditionally, PCTs and their predecessors have reported expenditure on the basis of inputs (e.g. total expenditure on pay and non-pay items). However, NHS policy-makers have for some time realised that this approach does not create clinically meaningful financial data or help in the design and evaluation of programmes of patient care. The Department of Health therefore initiated a 'Programme Budgeting' project. This has sought to create an accounting system that is more aligned with the distinct outputs and health outcomes of the health-care system. Since April 2003, in addition to its conventional accounting data, each PCT has prepared expenditure data disaggregated according to 23 programmes of health care. These programmes are defined by reference to the ICD-10 codes at the four-digit level, and most PBCs reflect ICD-10 chapter headings (e.g. cancer and tumours, circulation problems, renal problems, neonates, problems associated with the skin, problems associated with vision, problems associated with hearing, etc.). In some cases, the 23 categories are broken down into further subareas to achieve a closer match with the various NSFs; for example, the large mental health category is broken down into 'substance abuse', 'dementia', and 'other'.

Programme budgeting seeks to allocate all types of PCT expenditure to the various PBCs, including secondary care, community care and prescribing. However, the system acknowledges that a medical model of care may not always be appropriate, and two specific non-clinical groups – 'healthy individuals' and 'social care needs' – have been created. These are intended to capture the costs of disease-prevention programmes and the costs of services that support individuals with social rather than health-care needs. In addition, in some cases it is not possible to assign activity by medical condition, preventative activity, or social care need and, in these cases, expenditure is assigned to a residual category (PBC 23) entitled 'other'. The most important element of this residual programme is expenditure on GP services (PBC 23a). In principle, it should be possible to allocate each GP consultation to a particular care programme. However, at the moment the available data information systems do not permit such an allocation and so all primary care expenditure is allocated to this residual programme. The use of this residual category ensures that all expenditure is assigned to a programme of care.[73]

The aim of the programme budget classifications is to identify the entire volume of health-care resources assigned to broad areas of illness according to the primary diagnosis associated with an intervention. It serves a number of purposes, most notably to assist in the local planning of health care. However, for this study its crucial merit is that it opens up the possibility of examining the statistical relationship between local programme spending and the associated disease-specific outcome.

The collection of programme budgeting data

Programme budgeting information is collected centrally by the Department of Health as part of the annual accounts process. Each PCT is required to submit an annual PB return to the Department which shows how their total expenditure is allocated across the 23 PBCs.

Various forms of data collection and analysis are required to map PCT expenditure onto acute, community and other services to the 23 PBCs. From the PCT perspective, however, the construction of each PCT's return largely involves collating information provided by other bodies and drawing on other information

already in the PCT's own annual accounts. Thus GMS/PMS expenditure, which is already reported in PCT accounts, relates to direct primary care and is mapped in its entirety to PBC 23a (other: GMS/PMS); general ophthalmic service expenditure (again from PCT accounts) maps directly to PBC 8 (eye/vision problems); and general dental service expenditure maps directly to PBC 12 (dental problems). Prescribing and pharmaceutical services expenditure is allocated to PBCs on the basis of an annual apportionment report provided by the prescription pricing authority for each PCT as part of the annual accounts process. This apportionment report allocates each PCT's annual family health service prescribing expenditure across the 23 PBCs. The balance of any primary health care purchased by the PCT is allocated/apportioned across the 23 PBCs on the basis of local records, with any remaining expenditure allocated/apportioned in line with the distributions already made across the budget categories.

It is the responsibility of all NHS providers – which includes PCTs, NHS trusts, and foundation hospitals – to allocate admitted patient care expenditure across the PBCs, specific to each PCT that utilises its services. These allocations are constructed using 'finished consultant episodes' (FCEs) (from the mandatory administrative HES data set returned by each provider) each of which is assigned to a Healthcare Resource Group (HRG), an English version of Diagnosis-Related Groups. National grouping software automatically assigns each HRG to 1 of the 23 PBCs and attaches the provider's average reference cost for the relevant HRG to each record. For each PCT this information generates a split of inpatient care expenditure by PBC for each of its secondary health-care providers.

There are numerous difficulties faced when attempting to allocate non-admitted patient care activity (that is, outpatients, community services, direct access, A&E, etc.) to PBCs. The difficulties are primarily due to the absence of clear diagnostic codes. The 'primary reason for care' (equivalent to a diagnosis code) is not information that is routinely collected for community patients. Because of this, the approach prescribed is for service providers to produce a generic allocation analysis/report, for all PCTs making use of their services, for all non-admitted patient care costs across the 23 PBCs. Once derived, this generic allocation analysis/report is made available to PCTs at the same time as the unique (PCT-specific) inpatient care information described above. Unlike the first apportionment report relating to admitted patient care, the non-admitted patient care apportionment report will not be unique to the PCT, but will represent the provider's overall experience. PCTs are expected to use these data to inform the apportionment of their own spend on non-admitted patient care across the 23 PBCs.

The Department of Health recognises that this approach – the provision of a PCT-specific breakdown of admitted patient care costs and a generic allocation of all PCTs non-admitted patient care spend by providers – is likely to generate a crude method for apportioning non-admitted patient care costs. PCTs and their providers are therefore encouraged to put in place other arrangements that allow a more sophisticated analysis of non-admitted patient care expenditure. Such arrangements may well rely on an activity sampling approach.[73]

Mental health providers may not need to complete and forward detailed admitted and non-admitted patient care apportionment reports to PCTs. The nature of the services they provide may be such that the entire spend with them relates exclusively to the mental health programme (PBC 5). Ambulance trusts are required to provide non-admitted patient care information to those PCTs for whom they provide services. Where it is not possible to split the activity by PCT, a generic non-admitted patient care report is produced for all purchasers.[73]

The Department of Health has been criticised for the rather simplistic way in which it has apportioned certain costs among categories, and there are obvious issues with the allocation of costs associated with patients who have multiple disorders. However, the Programme Budgeting project is very much work-in-progress and the Department is investigating ways to improve the accuracy with which costs are allocated across programmes (e.g. the Department is investigating the possibility of allocating training expenditures to specific programmes rather than to the generic medical training programme PBC 23b).[d]

Programme budgeting expenditure, 2003/4–2008/9

National (all PCT) expenditure per head and the growth in this expenditure are shown for each PBC for 2003/4–2008/9 in *Table 1*. Comparable data for each programme budget subcategory are shown in *Table 91* in the *Annex*. Year-on-year comparisons of expenditure in each group are complicated by the fact that the algorithms used to allocate activity to PBCs are regularly revised. For example, for 2006/7 two major changes were made to the methods employed to construct the PB data. First, expert medical opinion was employed to re-evaluate the existing mapping from inpatient diagnosis codes to PBC. This led to the reassignment of just over 10% of all diagnosis (ICD-10) codes from one PBC to another.[e,f] Second, activity to be costed used the newly introduced version 4 of the HRG software which, among other things, changed the methodology for calculating non-admitted patient care costs. HRG4 reflected advances in clinical practice and was designed to generate a much more accurate costing of complex cases. Other developments, such as the transfer of responsibility for dental funding from local dental boards to PCTs, also complicate the interpretation of comparisons through time (e.g. per capita dental expenditure by PCTs increased from £13.55 in 2004/5 to £51.93 in 2006/7).

The expenditure figures for the first year (2003/4) are calculated on a slightly different basis to those for the other years (2004/5–2008/9). In particular, the figures for 2003/4 are on a 'net expenditure' basis whereas the figures for 2004/5–2008/9 are on an 'own population' basis. The 'own population' figure starts with net expenditure, it adds any expenditure funded from sources outside of the NHS, and then deducts any expenditure on other PCTs' populations incurred through lead/host commissioning arrangements. In 2006/7 and across all PBCs, expenditure per head on an own population basis was 2.3% greater than expenditure on a net population basis.

In 2004/5 total PCT expenditure per person was £1200. The category attracting the most expenditure was the 'other' category (PBC 23) with per capita expenditure of almost £158 (13.2%). This category included primary care expenditure, workforce training expenditure, and a range of other miscellaneous expenditure items. Of these components, primary care expenditure was by far the largest element at £127 per head.

In 2004/5 there were two other categories with a budget share of over 10%: mental health (PBC 5) attracted 12.2% of expenditure (£147 per person), and circulation problems (PBC 10) recorded 10.2% of expenditure (£122 per person). Seven PBCs – cancers and tumours (£76), gastrointestinal problems (£73), trauma and injuries (£72), musculoskeletal problems (£72), respiratory problems (£63), genitourinary problems (£62) and maternity and reproductive conditions (£55) – had expenditure shares of between 4.6% and 6.3%. Finally, the 13 remaining PBCs – from hearing problems (£6) to learning disability (£43) – each account for between 0.5% and 3.6% of total expenditure.

By 2008/9 total PCT expenditure per person had increased to £1531 (up 28% from 2004/5). The residual 'other' category (PBC 23) still accounted for the largest share of expenditure (14.9%) with per capita expenditure of almost £228, of which £145 was accounted for by primary care expenditure. Mental health (PBC 5) still accounted for just over 12% of expenditure, but the expenditure share recorded by circulation problems (PBC 10) had fallen from 10.2% to 8.5%. Other categories recording a fall in budget share of more than one half of one percentage point included the gastrointestinal system (down from 6.1% to 5.1%), the musculoskeletal system (down from 6% to 5.2%), trauma and injuries (down from 6% to 4.2%) and maternity (down from 4.6% to 3.9%).

Categories recording an increase in budget share of more than one half of one percentage point included neurological problems (up from 2.9% to 4.4%) and dental problems (up from 1.1% to 4.1%).

Some of these changes will partly reflect revisions to the algorithms used to allocate expenditure to particular PBCs. For example in 2006/7 expenditure per person on musculoskeletal problems fell by 11% and expenditure on trauma and injuries fell by 25%. In the same year, expenditure on neurological problems increased by 35%. This suggests that some types of activity, which were previously allocated to musculoskeletal problems and/or trauma and injuries, were reallocated to neurological problems.

Similarly, up to and including 2006/7, expenditure that was not directly attributable to a particular programme category was apportioned using admitted patient care percentages.[g] In other words, if *x*% of total admitted patient care expenditure was allocated to PBC 1, then *x*% of all expenditure that was not directly attributable to a particular programme category was also allocated to PBC 1. With effect from 2007/8, however, NHS organisations were asked to select an appropriate basis for the apportionment of this non-programme-specific expenditure and that, where no reasonable basis existed, such expenditure was to be allocated to the 'other – miscellaneous' (PBC 23X) category.

These two changes to the algorithm used to allocate expenditure to particular PBCs illustrate that year-on-year comparisons of expenditure need to be interpreted with care.

Obviously, expenditure per head on any given programme varies from one PCT to another and *Table 2* presents some statistics that indicate the degree of variation in expenditure levels across PCTs by PBC. Columns (2)–(5) of *Table 2* present descriptive statistics for PCT expenditure per person by PBC. These reveal that, for example, PCT per capita expenditure in the cancer programme averaged £96.30 across all PCTs, with the minimum spend being £62.90 and the maximum being £155.70.

Some PCTs will be spending more than other PCTs simply because they face higher input costs. Columns (6)–(9) in *Table 2* present descriptive statistics for PCT per capita expenditure that has been adjusted for the unavoidable geographical variation in costs (input prices) faced by PCTs.[h] However, if anything this adjustment appears to increase the variation in expenditure across PCTs; for example, the range of per capita expenditure on cancer increases from between £62.90 and £155.70 (unadjusted) to between £59.10 and £163.10 (adjusted for local health-care input prices).

Another cause of the variation in expenditure levels will be the fact that the need for health care will vary from one PCT to another. For example, areas with a relatively large proportion of elderly residents, or PCTs operating in relatively deprived locations, can be expected to experience relatively high levels of spending. The Department of Health has a well-developed methodology for estimating the relative health-care needs of PCTs, which it uses as the basis for allocating health-care funds to PCTs.[74] Recent 'needs' formulae have been derived from an adjustment for the demographic profile of the PCT and a series of econometric analyses of the link between health-care expenditure and other socioeconomic factors at a small area level within England.[74]

Columns (10)–(13) in *Table 2* present descriptive statistics for PCT per capita expenditure that has been adjusted for both the unavoidable geographical variation in costs and the local need for health care faced by PCTs.[i] For virtually every PBC this adjustment reduces the variation in expenditure across PCTs (e.g. the standard deviation of PCT per capita expenditure, falls from £19.70 to £15.30 for the cancer programme). Although this adjustment reduces the variation in expenditure levels across PCTs, this decline is quite modest and there are still substantial differences in expenditure even after allowing for differences in local cost and need. For example, expenditure per head in the circulation problems category varies between £78 and £328 using cost-adjusted expenditure data, but falls between £76 and £327 using cost- and need-adjusted population data.

This variation in expenditure across PCTs has led some commentators to question the reliability of the PB data. In a good governance report, the NAO[75] sought to ' . . . examine the quality, timeliness and suitability of PB data to support [their] audit of the Department of Health Resource Account and determine whether the systems and processes in place to provide the data are accurate'. The NAO undertook a survey of trusts, PCTs and SHAs. The NAO noted that a number of PCTs expressed concern about the accuracy of data supplied to them by their service providers and noted that this was believed to be because most trusts did not use or find the data they supply to PCTs of any use to themselves. Overall, the NAO's main conclusion was that although the processes for collecting the budgeting data were well defined in most areas, there remained scope for improvement to the robustness of some of the data (such as the non-admitted patient care data).

Appleby *et al.*[76] also considered the issue of data reliability in their study of variations in PCT spending on cancer services. They noted a rather dramatic variation in spending across PCTs for any given year, and that a relatively large number of PCTs report relatively large year-on-year changes in cancer expenditure. However, and as the authors point out, it is difficult to define what might be either an implausible level of expenditure or an implausibly large change in expenditure. Moreover, the interpretation of a large change in expenditure is complicated by the fact that the Department of Health makes regular changes (improvements) to the algorithm used to allocated activity to PBCs (as detailed above).

As a case study of the reliability of the PB data, Appleby *et al.*[76] report the results of West Kent PCT's use of an alternative approach to producing the PB data for cancer and tumours. This alternative approach identified similar levels of expenditure to the traditional method at the aggregate level, but there were differences between the two approaches at the subprogramme level (that is, for expenditure on specific cancer sites and in the residual 'other cancers' category).

As with any data set, there are likely to be recording and other errors associated with the PB data. However, there is no evidence on the magnitude of such errors and we have no reason to believe that such errors are likely to bias our estimates in one particular direction (e.g. we have no reason to believe that measurement errors are systematically related to other relevant factors such as mortality rates). In this study, our focus is on whole programme expenditure and thus we avoid the data reliability issues inherent in any analysis of the subprogramme expenditure data.[j] Moreover, although we present estimates of the cost of a life-year for individual programmes, our primary focus is on the cost of a life-year across *all* programmes combined. The advantage of this is that the impact of a PCT reporting, for example, too little expenditure in one category might be offset by reporting too much expenditure in another.

Although we note that the allocation of expenditure might not be consistent across PCTs there is no systematic evidence that the magnitude of any inconsistency is sufficiently large to cause concern. Accordingly, for each disease category, the observed variation in expenditure per person – holding constant input prices and the need for health care – offers the opportunity to examine whether or not PCTs that spend more on health care achieve a better outcome and, if so, at what cost. Empirical estimates of the strength of this relationship for both individual and all programmes of care are presented later in this report.

Health outcome and other data

Health outcome data

Most studies of the relationship between expenditure and outcome have used some measure of mortality as an indicator of the latter. We too employ mortality as our outcome measure for two reasons: first, it is a relevant (but admittedly not comprehensive) measure of the outcome of health-care expenditure; and second, it is available for more disease areas than any other outcome measure at PCT level.

Although mortality is available (by PCT) for several disease areas, it is not available for just over a half of all programmes not least because it is simply not relevant for these programmes (e.g. for learning disabilities, vision problems, hearing problems, dental problems and skin problems). Moreover, even where a mortality measure is available, the ICD-10 coverage of the mortality data often falls short of the coverage of the expenditure data. For some programmes, therefore, we have combined the published mortality rates for two or more disease areas in an attempt to match the ICD-10 coverage of the mortality data with that of the expenditure data.

Table 37 shows how we have attempted to marry the mortality data [see *Table 37*, column (4)] and the expenditure data [see *Table 37*, column (2)]. However, and as *Table 37* shows, the ICD-10 coverage of the component mortality rates for some PBCs still falls short that of the expenditure data and the extent of this shortfall is illustrated by the ratio reported in the final column of *Table 37*. For example, the cancers and tumours programme covers all expenditure associated with ICD-10 codes C00–C97 and D00–D49 but

TABLE 37 Table showing ICD-10 coverage of the expenditure and outcome measures

(1) PBC	(2) ICD-10 coverage of PBC	(3) Number of deaths, < 75 years, 2008, England (ONS, VS3) corresponding to column (2) ICD-10 codes	(4) ICD-10 coverage of best match PCT-based mortality rate(s)	(5) Number of deaths, < 75 years, 2008, England (ONS, VS3) corresponding to column (4) ICD-10 codes	(6) Ratio [column (5)/ column (3)]
1	Infectious diseases (large parts of A00–B99)	1968	Infectious diseases (A00–B99)	1968	1
2	Cancers and tumours (C00–C97, D00–D49)	63,076	All cancers (C00–C97)	62,072	0.984
3	Blood disorders (D500–D899)	393	No relevant mortality rate by PCT available	N/A	N/A
4	Endocrine, nutritional and metabolic problems (E000–E899)	2368	Diabetes (E10–E14)	1501	0.634
5	Mental health (F00–F69, Z55, Z56)	N/A	No relevant mortality rate available	N/A	N/A
6	Learning disability (F700–F739, F780–F849, F88–F90, Q90, Q91)	N/A	No relevant mortality rate available	N/A	N/A
7	Neurological system (G000–G999, Q000–Q079, R200–R999)	5238	Epilepsy (G40–G41)	713	0.136
8	Eye and vision problems (H000–H599, Q100–Q159)	N/A	No relevant mortality rate available	N/A	N/A
9	Hearing problems (H600–H999, Q160–Q179)	N/A	No relevant mortality rate available	N/A	N/A
10	Circulation problems (I00–I99, Q20–Q28)	39,923	Circulatory diseases (I00–I99)	39,590	0.992
11	Respiratory problems (A150–A169, A190–A199, J000–J989, Q300–Q349, R000–R099)	14,417	Asthma (J45–J46); bronchitis, emphysema, other COPD (J40–J44); pneumonia (J12–J18)	11,147	0.773

continued

TABLE 37 Table showing ICD-10 coverage of the expenditure and outcome measures (*continued*)

(1) PBC	(2) ICD-10 coverage of PBC	(3) Number of deaths, < 75 years, 2008, England (ONS, VS3) corresponding to column (2) ICD-10 codes	(4) ICD-10 coverage of best match PCT-based mortality rate(s)	(5) Number of deaths, < 75 years, 2008, England (ONS, VS3) corresponding to column (4) ICD-10 codes	(6) Ratio [column (5)/ column (3)]
12	Dental problems (K000–K099)	N/A	No relevant mortality rate available	N/A	N/A
13	Gastrointestinal problems (I840–I859, K091–K929, Q380–Q459, R100–R198)	10,656	Liver disease (K70, K73–K74); ulcers (K25–K27)	6082	0.571
14	Skin problems (L000–L999, Q351–Q379, Q800–Q859)	367	No relevant mortality rate available	N/A	N/A
15	Musculoskeletal problems (M00–M99, Q18, Q650–Q799)	933	No relevant mortality rate available	N/A	N/A
16	Trauma, burns and injuries (S000–S999, T000–T357, T79, T90–T98)	5809	Skull, cranial injury (S02, S06, T90); fracture of thighbone (S72)	1014	0.175
17	Genitourinary problems (A50–A64, N00–N99, Q500–Q649, R30–R39, R86–R87)	1565	Chronic renal failure (N18)	269	0.172
18	Maternity and reproductive problems (N96–N98, O000–O999, Z300–Z391)	41	No relevant mortality rate available	N/A	8.213, but see note below
19	Neonate conditions (P000–P299, P350–P399, P500–P619, P700–P839, P900–P969)	226	Infant mortality rate per 1000 live births, aged < 28 days (all ICD-10 codes)	4345	8.213, but see note below
20	Poisoning (Q86, R78, R82, T360–T888)	N/A	No relevant mortality rate available	N/A	N/A
21	Healthy individuals	N/A	No relevant mortality rate available	N/A	N/A
22	Social care needs	N/A	No relevant mortality rate available	N/A	N/A

COPD, chronic obstructive pulmonary disease; N/A, not applicable.
The listed ICD-10 coverage of the PB expenditure data includes the major ICD-10 codes covered.
The ICD-10 coverage of PBC 1 includes large elements of codes A00–B99 but a substantial minority of these codes map to the respiratory (PBC 11) and gastrointestinal (PBC 13) programmes. We do not have the detailed deaths data to remove them from the total for A00–B99 and then to add them to the respiratory and gastrointestinal programmes. Instead, we acknowledge that the number of deaths attributed to PBC 1 will be overstated [and that the adjustment ratio in column (6) will be too low], and that the number of deaths attributed to PBCs 11 and 13 will be understated [and that their adjustment ratios in column (6) will be too high] but this is the best that can be achieved given the available data.
The ICD-10 coverage of the all England mortality data does not always match precisely that of the expenditure data or the PCT-level mortality data; again, we have done the best that can be achieved given the available data. In particular, the national epilepsy mortality data relates to ICD-10 code G40 (687 deaths) but the PCT-level data relates to G40 and G41 (annual average over 2007/8/9 is 713 deaths); the national renal failure mortality data relates to ICD-10 codes N17–N19 (415 deaths) but the PCT-level data relates to N18 (annual average over 2007/8/9 is 269 deaths); the national liver disease mortality data relates to ICD-10 code K70–K77 (6020 deaths) but the PCT-level data relates to K70, K73–K74 (annual average over 2007/8/9 is 5195 deaths); and there is no good ICD-10 code match for femur and skull fracture deaths using national VS3 data (the PCT-level data relates to S72, S02, S06, T90: annual average over 2007/8/9 is 1014 deaths). For these four cases we use the annual average number of deaths over 2007/8/9 from the PCT-level data as the numerator when calculating the coverage adjustment factor [column (6)].
The number of deaths in England for those aged < 75 years for the trauma, burns and injuries programme [column (3)] relates to 2004 and is for the secondary cause of death (Martin *et al.*[63]).
The mortality rate for neonate conditions relates to deaths aged < 28 days for all ICD-10 codes but the expenditure data relates only to 'P' ICD-10 codes. Hence, the large adjustment factor of 8.213 because the coverage of the expenditure data is much smaller than that of the mortality data. However, at the very end of the project it became clear that although the number of deaths data for those aged < 75 years includes those dying at all ages < 75 years (including those at < 1 year), the disease-specific years of life lost totals for those aged < 75 years excludes those dying at < 1 year of age and actually refers to those dying at ages 1–74 years (the argument is that infant deaths are mostly a result of causes specific to the age and have different causes to disease-specific deaths later in life). We therefore have two adjustment factors for the maternity and neonates programme: first, an adjustment factor for the number of deaths derived on the same basis as the adjustment factors for other programmes; and second, an adjustment factor for the YLL that reflects both the YLL in the maternity and neonates programme, as well as the YLL associated with deaths that would have been attributed to other programmes had the individual died > 1 year of age. [NB The total number of deaths in England in 2008 of those aged < 1 year is 3184 and if we divide 2193 by (3184 + 41) we obtain the YLL coverage adjustment factor (= 0.679) for maternity and neonates.]
The PCT-level mortality rates are available from the NHS IC website.

the PCT-based mortality data only relates to ICD-10 codes C00–C97. At the national (all England) level, figures are available which show that, in 2008, there were 62,072 deaths of those aged under 75 years from codes C00–C97 and that there were 63,076 deaths from codes C00–C97 and D00–D49 combined. In other words, the PCT-level mortality data reflects 98.4% of all deaths associated with the expenditure codes. Initially, we did not adjust our cost of life (year) estimates for this mismatch but, as we will see in *Adjusting the cost of life (year) estimates for the mismatch in the ICD-10 coverage of the expenditure and the mortality data*, an adjustment has been made for this mismatch in the final calculation of the cost of a life (year) associated with expenditure for 2006/7. The same adjustment has also been applied to the cost of a life (year) estimates associated with expenditure for 2007/8 and for 2008/9.

Of course, we acknowledge that mortality is a more relevant outcome indicator for some programmes (e.g. for circulatory problems) than for others (e.g. for epilepsy) and, for this reason, we would expect better results in some programmes than others. We also acknowledge that this focus on mortality ignores the impact of expenditure aimed at chronic care and at palliative care. Nevertheless, our focus on mortality is purely practical: it is both a widely available measure and it is clearly a relevant outcome indicator. Moreover, the approach adopted here is extendable in principle to other non-mortality-based outcome indicators. We illustrate such an application in *Application of method to other non-mortality-based outcome indicator* where we use EQ-5D utility scores pre and post an operative procedure from the PROMs programme to generate a non-mortality-based outcome indicator, and we use this indicator to estimate our outcome model.

Previous studies using the PB data have employed two alternative mortality-based outcome indicators: the under 75 years of age SMR and the under 75 years SYLLR. The SMR gives equal weight to all deaths irrespective of the age at which they occur but the SYLLR gives greater weight to deaths that occur at earlier ages.

We employed both the SMR and the SYLLR when undertaking some preliminary sens7itivity analysis (i.e. in *Estimation issues associated with the use of 2006/7 expenditure data* when considering, for example, which measure of need to use), but elsewhere we have focussed solely on a measure of the avoidable YLL.[k] This is calculated by summing over ages 1–74 years the number of deaths at each age multiplied by the number of years of life remaining up to age 75 years. The crude YLL rate is simply the number of YLL divided by the resident population aged < 75 years. Like conventional mortality rates, the crude YLL rate can be age standardised to eliminate the effects of differences in population age structures between areas, and this (age) standardised YLL rate is the health outcome variable generally employed in this study (Lakhani *et al.*, p. 379).[77]

Descriptive statistics for the SYLLRs employed in this study are shown in *Table 38*. For example, for all deaths over the 3-year period from 2006 to 2008, the annual SYLLR across all PCTs for those aged < 75 years averaged 467 YLL per 10,000 population, but this rate varied considerably across PCTs, ranging between 288 and 749 YLL per 10,000 population. Similarly, large variations in the mortality rate across PCTs are evident for other disease groups.[l]

Other variables

We employ an IV estimation technique to estimate our outcome and expenditure equations because (i) own programme expenditure is likely to be endogenous in the outcome equation and (ii) other programme need is likely to be endogenous in the own programme expenditure equation.

Instrumental variable estimation is described in *Instrumental variable estimation*, below, but basically it involves replacing the endogenous variable in the equation of interest with its predicted value from an OLS regression which regresses the endogenous variable on a set of IVs. These instruments should be good predictors of the endogenous variable (i.e. they should be relevant and strong predictors) but should be appropriately excluded from the equation of interest (i.e. they should be valid instruments).

TABLE 38 Table showing descriptive statistics for the mortality variables

Variable	Observations	Mean	SD	Min.	Max.
All causes of death, SYLLR, 2002/3/4	303	489.2	94.2	320.3	889.5
All causes of death, SYLLR, 2004/5/6	152	483.4	83.9	318.1	742.5
All causes of death, SYLLR, 2006/7/8	152	467.3	83.7	287.8	748.9
All causes of death, SYLLR, 2007/8/9	151	457.1	81.8	297.2	731.6
All causes of death, SYLLR, 2008/9/10	151	446.4	78.6	290.8	736.9
Cancer, SYLLR, 2002/3/4	303	161.9	20.8	115.6	263.4
Cancer, SYLLR, 2004/5/6	152	158.4	18.3	103.4	218.8
Cancer, SYLLR, 2006/7/8	152	154.2	19.0	90.5	212.2
Cancer, SYLLR, 2007/8/9	151	151.0	18.5	98.3	201.9
Cancer, SYLLR, 2008/9/10	151	147.9	17.5	100.2	193.9
Circulatory disease, SYLLR, 2002/3/4	303	114.4	31.3	57.7	225.7
Circulatory disease, SYLLR, 2004/5/6	152	108.6	25.2	65.2	177.8
Circulatory disease, SYLLR, 2006/7/8	152	99.0	23.7	54.4	156.7
Circulatory disease, SYLLR, 2007/8/9	151	94.4	22.6	51.4	149.9
Circulatory disease, SYLLR, 2008/9/10	151	91.1	21.7	50.9	154.8
Asthma, SYLLR, 2002/3/4	303	2.7	2.0	0.0	12.2
Asthma, SYLLR, 2004/5/6	152	2.4	1.3	0.1	6.3
Asthma, SYLLR, 2006/7/8	152	2.0	1.1	0.0	5.0
Asthma, SYLLR, 2007/8/9	151	1.9	1.1	0.0	5.7
Asthma, SYLLR, 2008/9/10	151	1.7	1.1	0.0	4.6
Bronchitis, emphysema and other COPD, SYLLR, 2002/3/4	303	12.5	5.7	2.6	35.5
Bronchitis, emphysema and other COPD, SYLLR, 2004/5/6	152	12.0	4.8	3.7	26.1
Bronchitis, emphysema and other COPD, SYLLR, 2006/7/8	152	12.0	4.8	4.0	24.4
Bronchitis, emphysema and other COPD, SYLLR, 2007/8/9	151	11.8	4.7	4.1	24.8
Bronchitis, emphysema and other COPD, SYLLR, 2008/9/10	151	11.6	4.9	4.2	26.6
Pneumonia, SYLLR, 2002/3/4	303	9.1	4.1	1.4	24.6
Pneumonia, SYLLR, 2004/5/6	152	9.7	3.7	3.6	21.9
Pneumonia, SYLLR, 2006/7/8	152	9.7	3.9	3.6	32.4
Pneumonia, SYLLR, 2007/8/9	151	9.8	4.0	3.9	34.4
Pneumonia, SYLLR, 2008/9/10	151	9.3	4.0	2.8	36.1
Tuberculosis, SYLLR, 2002/3/4	N/A				
Tuberculosis, SYLLR, 2004/5/6	152	0.8	1.1	0.0	5.2
Tuberculosis, SYLLR, 2006/7/8	152	0.8	1.0	0.0	7.6
Tuberculosis, SYLLR, 2007/8/9	N/A				
Tuberculosis, SYLLR, 2008/9/10	N/A				
Respiratory problems, SYLLR, 2002/3/4 (excluding TB)	303	24.3	9.7	5.4	64.2
Respiratory problems, SYLLR, 2004/5/6 (including TB)	152	24.9	8.9	9.7	51.7

continued

TABLE 38 Table showing descriptive statistics for the mortality variables (*continued*)

Variable	Observations	Mean	SD	Min.	Max.
Respiratory problems, SYLLR, 2006/7/8 (including TB)	152	24.6	8.5	11.3	56.4
Respiratory problems, SYLLR, 2007/8/9 (excluding TB)	151	23.4	8.1	8.5	57.4
Respiratory problems, SYLLR, 2008/9/10 (excluding TB)	151	22.6	8.5	8.5	65.0
Liver disease, SYLLR, 2002/3/4	303	20.1	10.0	3.6	70.9
Liver disease, SYLLR, 2004/5/6	152	22.9	9.9	8.2	75.0
Liver disease, SYLLR, 2006/7/8	152	23.9	10.8	7.0	81.7
Liver disease, SYLLR, 2007/8/9	151	23.7	10.6	9.4	81.1
Liver disease, SYLLR, 2008/9/10	151	23.5	9.9	8.4	77.4
Gastric, duodenal and peptic ulcers, SYLLR, 2002/3/4	303	2.6	1.6	0.0	10.2
Gastric, duodenal and peptic ulcers, SYLLR, 2004/5/6	152	2.7	1.5	0.1	11.6
Gastric, duodenal and peptic ulcers, SYLLR, 2006/7/8	152	2.4	1.3	0.5	8.5
Gastric, duodenal and peptic ulcers, SYLLR, 2007/8/9	151	2.4	1.3	0.4	7.0
Gastric, duodenal and peptic ulcers, SYLLR, 2008/9/10	151	2.3	1.4	0.4	7.6
Gastrointestinal problems, SYLLR, 2002/3/4	303	22.7	11.0	4.7	77.8
Gastrointestinal problems, SYLLR, 2004/5/6	152	25.6	10.7	9.3	80.3
Gastrointestinal problems, SYLLR, 2006/7/8	152	26.3	11.5	8.1	87.6
Gastrointestinal problems, SYLLR, 2007/8/9	151	26.1	11.1	10.7	86.3
Gastrointestinal problems, SYLLR, 2008/9/10	151	25.8	10.5	9.2	82.5
Infectious diseases, SYLLR, 2002/3/4	303	7.0	4.2	0.1	28.1
Infectious diseases, SYLLR, 2004/5/6	152	8.1	4.3	2.4	24.9
Infectious diseases, SYLLR, 2006/7/8	152	8.3	4.4	0.6	26.1
Infectious diseases, SYLLR, 2007/8/9	151	8.2	4.2	2.1	25.1
Infectious diseases, SYLLR, 2008/9/10	151	7.7	4.0	1.6	22.6
Diabetes, SYLLR, 2002/3/4	303	4.7	2.3	0.0	13.4
Diabetes, SYLLR, 2004/5/6	152	4.5	2.1	1.3	15.3
Diabetes, SYLLR, 2006/7/8	152	4.3	2.0	0.5	14.6
Diabetes, SYLLR, 2007/8/9	151	4.0	1.8	0.3	11.2
Diabetes, SYLLR, 2008/9/10	151	4.0	1.7	0.4	10.0
Epilepsy, SYLLR, 2002/3/4	303	5.2	2.7	0.3	16.1
Epilepsy, SYLLR, 2004/5/6	152	5.3	2.1	0.5	13.1
Epilepsy, SYLLR, 2006/7/8	152	5.1	2.1	0.9	12.7
Epilepsy, SYLLR, 2007/8/9	151	4.9	1.9	1.3	14.5
Epilepsy, SYLLR, 2008/9/10	151	4.8	2.0	1.1	13.7
Renal failure, SYLLR, 2002/3/4	303	0.9	0.9	0.0	6.0
Renal failure, SYLLR, 2004/5/6	152	0.9	0.7	0.0	4.0
Renal failure, SYLLR, 2006/7/8	152	0.8	0.7	0.0	5.5
Renal failure, SYLLR, 2007/8/9	151	0.7	0.6	0.0	4.3
Renal failure, SYLLR, 2008/9/10	151	0.6	0.6	0.0	3.0

TABLE 38 Table showing descriptive statistics for the mortality variables (*continued*)

Variable	Observations	Mean	SD	Min.	Max.
Fracture of femur (S72), SMR, 2002/3/4 (ages 65–84 years)	303	8.9	6.9	0.0	39.3
Fracture of femur (S72), SMR, 2004/5/6 (ages 65–84 years)	152	10.1	6.6	0.0	30.6
Fracture of femur (S72), SMR, 2006/7/8 (ages < 75 years)	152	0.4	0.3	0.0	1.4
Fracture of femur (S72), SYLLR, 2007/8/9 (ages < 75 years)	151	0.3	0.3	0.0	1.7
Fracture of femur (S72), SYLLR, 2008/9/10 (ages < 75 years)	151	0.3	0.3	0.0	2.1
Skull fracture/injury, SMR, 2002/3/4 (ages < 75 years)	303	2.8	1.2	0.4	7.6
Skull fracture/injury, SMR, 2004/5/6 (ages < 75 years)	152	1.9	0.8	0.4	4.4
Skull fracture/injury, SMR, 2006/7/8 (ages < 75 years)	152	1.8	0.7	0.5	4.2
Skull fracture/injury, SYLLR, 2007/8/9 (ages < 75 years)	151	1.7	0.7	0.2	4.2
Skull fracture/injury, SYLLR, 2008/9/10 (ages < 75 years)	151	1.6	0.6	0.1	3.0
Trauma, SMR, 2002/3/4 (weighted average of femur and skull fractures)	303	4.8	2.4	0.3	15.3
Trauma, SMR, 2004/5/6 (sum of femur and skull fracture rates)	152	12.0	6.8	1.9	32.8
Trauma, SMR, 2006/7/8 (sum of femur and skull fracture rates)	152	2.1	0.8	0.6	4.7
Trauma, SMR, 2007/8/9 (sum of femur and skull fracture rates)	151	2.1	0.8	0.2	4.6
Trauma, SMR, 2008/9/10 (sum of femur and skull fracture rates)	151	1.9	0.8	0.1	4.4
Infant mortality rate, < 28 days per 1000 live births, 2002/3/4	303	3.4	1.3	0.9	7.8
Infant mortality rate, < 28 days per 1000 live births, 2004/5/6	130	3.4	0.9	1.2	6.2
Infant mortality rate, < 28 days per 1000 live births, 2006/7/8	152	3.3	1.0	1.4	6.4
Infant mortality rate, < 28 days per 1000 live births, 2007/8/9	151	3.2	1.0	1.2	6.9
Infant mortality rate, < 28 days per 1000 live births, 2008/9/10	151	3.2	1.0	1.2	6.9

COPD, chronic obstructive pulmonary disease; max., maximum; min., minimum; N/A, not applicable; SD, standard deviation, TB, tuberculosis.
The SYLLRs are directly age-standardised rates and are expressed as rates per 10,000 European standard population.
Source: NHS IC website.

We have a number of potential instruments available, mostly derived from 2001 Population Census.[80] In our earlier studies we found that a small subset of these instruments proved sufficient to generate plausible results and these included:

- the proportion of the population providing unpaid care
- the proportion of households that are one-pensioner households
- the index of multiple deprivation
- the proportion of the population in the white ethnic group.

We also had available a further set of potential instruments and, where our more limited set of instruments failed to generate plausible results, we extended our instrument search to include this wider set of variables. This extended set of instruments included:

- the proportion of residents born outside the EU
- the proportion of the population of working age (16–74 years) with a limiting long-term illness (LLT)
- the proportion of the population aged 16–74 years with no qualifications
- the proportion of the population aged 16–74 years who are full-time students

- the proportion of households without a car
- the proportion of households that are owner occupied
- the proportion of households that are rented from a local association (LA) or housing association (HA)
- the proportion of households that are rented from private landlords
- the proportion of households that are lone-parent households with dependent children
- the proportion of the population aged 16–74 years who are permanently sick
- the proportion of those aged 16–74 years who are long-term unemployed
- the proportion of those aged 16–74 years in employment who are working in agriculture
- the proportion of those aged 16–74 years in managerial and professional occupations.

Details of the construction of all instruments are shown in *Table 92* in the *Annex*.

Our instruments reflect factors, such as socioeconomic deprivation and the availability of informal care in the community, which might indirectly impact on mortality rates and/or health-care expenditure levels. As we shall see, although our instruments 'pass' the appropriate statistical tests, some commentators claim that such tests may have 'low power' to detect the presence of invalid instruments. Consequently, in *The sensitivity of the outcome elasticity to the validity of the instrument exclusion restrictions* we examine how sensitive our results are to the presence of invalid instruments.

Table 3 reports descriptive statistics for the socioeconomic and needs variables as available for the regression analysis of PB expenditure data for 2007/8 and for 2008/9 (these statistics are for the variables in absolute form). For example, on average, lone-pensioner households comprise 14% of all households, the 'white ethnic' group accounts for 89% of the population, and 10% of the population provide unpaid care.

In addition to the IVs, *Table 3* also report descriptive statistics for various other variables available for the regression analysis including the of Department of Health's 'need for health care' index (this incorporates the CARAN formula for HCHS and reflects need across all health-care services), its need for HIV services index, and its need for maternity services index. The latter two indices are used to either supplement or replace the all service measure of need when estimating our models. The 'need for health care' index averages about 1 but varies substantially, with some PCTs having a needs index more than 25% below the national average and others facing a need for health care more than 30% above the national average.

Table 3 also reports descriptive statistics for some disease prevalence rates (e.g. for diabetes and for epilepsy) and, again, these are used to either supplement or replace the all service measure of need when estimating our models.

Finally, the MFF index shows that input prices in the most expensive PCT are almost 20% above those in the least expensive PCT.

Estimation issues and strategy

Introduction

The theoretical framework suggests the specification and estimation of a system of equations, with an expenditure and health outcome equation for each of the 23 programmes of care. However, this approach makes infeasible data demands, requiring variables to identify expenditure, need, environmental factors and health outcomes in each of the 23 programmes of care. Moreover, mortality rates are available for less than half of the 23 programmes. Rather than estimate a system of equations, we proceed on a programme-by-programme basis, estimating health outcome and expenditure equations for those programmes for which mortality data is available.

In line with the theoretical framework presented in *Theoretical model*, we specify the following expenditure (see *Equation 12*) and health outcome (see *Equation 13*) models for each of the *J* programmes of care ($J = 23$):

$$x_i = a_1 + \sum b_{1j} \cdot n_{ij} + dy_i + e_{1i} \; j = 1, \ldots, 23 \tag{12}$$

$$h_i = a_2 + b_2 n_i + f x_i + e_{2i} \tag{13}$$

where:

- x_i is the expenditure in PCT_i in the selected programme
- n_{ij} is the need for care in PCT_i in programme $_j$
- y_i is the total budget for PCT_i
- h_i is the health gain in PCT_i in the selected programme
- n_i is the need for care in PCT_i in the selected programme.

Ideally we should employ a programme-specific indicator of the level of need for each care programme but these are not readily available. When estimating both the outcome and expenditure models we therefore proxy the own programme health-care need using the 'needs' component of the Department of Health's resource allocation formula.[m] This needs element is specifically designed to adjust PCT allocations for local health-care needs and accordingly, ceteris paribus, we would expect a positive relationship between expenditure x_i and need n_i for each programme of care. We would also expect a positive relationship between need n_i and adverse health outcomes h_i.[n]

The expenditure model includes both the own programme health-care need (which is proxied using the 'needs' component of the Department of Health's resource allocation formula) and the need for health care in all other programmes. When estimating the expenditure model previous studies have proxied the need for health care in other (competing) programmes using the mortality rate in those other programmes. The precise definition of the programmes included in the 'other programme' mortality rate has varied a little, but here all of our preferred results from 2006/7 onwards use the 'all-cause mortality rate excluding the mortality rate in the programme of interest' as the proxy for need in other programmes.[o]

Instrumental variable estimation

We do not use OLS to estimate *Equations 12* and *13* because both are likely to contain an endogenous regressor. Expenditure in the outcome equation (see *Equation 13*) and other programme need in the expenditure equation (see *Equation 12*) are both likely to be endogenous and, in the presence of an endogenous regressor, OLS is both a biased and an inconsistent estimator. Instead, we use IV estimation and implement 2SLS using the -ivreg2- routine in Stata v11. Unlike OLS, IV is a consistent estimator in the presence of an endogenous regressor and, although in finite samples the IV estimator will be biased, the belief is that (providing certain assumptions are met) this bias will be less than that associated with OLS.

For the health outcome equation, IV estimation can be viewed as finding variables (instruments) that are good predictors of programme expenditure but which are appropriately excluded from the equation of interest (that is, from *Equation 13*). The assumption is that the instruments and exogenous variables from the equation of interest impact on the health outcome through their impact on expenditure only, and that they do not have a direct effect on the outcome.[p] If, on the other hand, an instrument reflects unobserved factors that affect both expenditure and mortality directly, then the IV estimator becomes both biased and inconsistent. Such an instrument is said to be 'invalid' because it belongs in the equation of interest in its own right.

We have a number of potential instruments available, mostly derived from the 2001 Population Census,[80] and these are described in *Other variables*. In our earlier studies we found that a small subset (four) of these instruments often proved sufficient to generate plausible results and we commenced our empirical work with these. If plausible results were not obtainable with some combination of these four instruments, we employed an extended instrument set. Further details of the identification of suitable instruments for each model can be found in *Re-estimation of poorly performing models with an extended instrument set*.

The available instruments reflect factors, such as socioeconomic deprivation and the availability of informal care in the community, which might indirectly impact on mortality rates and/or health-care expenditure levels. The set of instruments associated with each estimated equation was selected on both technical and pragmatic grounds. From a pragmatic point of view, we require a parsimonious set of instruments that satisfy the necessary technical criteria. These are, first, that they have face validity, that is, that they are plausible determinants of the endogenous variable being instrumented, and second, that the instruments are both relevant and valid. The relevance of an instrument set refers to its ability to predict the endogenous variable of concern, whereas validity refers to the requirement that instruments should be uncorrelated with the error term in the equation of interest. The set of instruments was modified if, for example, the Hansen–Sargan test suggested that the set under test was not valid.

Should the instrument set be strong, relevant and valid, 2SLS will produce consistent estimates of the parameters of the reduced form models. We subject the instrument sets to tests for validity using the Sargan–Hansen test of overidentifying restrictions. The joint null hypothesis is that the instruments are valid instruments (i.e. they are uncorrelated with the error term), and that the excluded instruments are correctly excluded from the estimated equation. A rejection of the null hypothesis casts doubt on the validity of the instruments. We test for instrument relevance using Shea's[79] partial R^2 measure; this reflects the correlation between the excluded instruments and the endogenous regressor. However, even if valid and relevant, non-zero but small correlations between the instruments and the endogenous regressors can lead to the problem of weak instruments. This can be the case even where correlations are shown to be significant at conventional levels of testing and sample sizes are large.[143] The IV estimator becomes a biased estimator if the instruments are weakly correlated with the endogenous regressors, and the extent of the bias can be specified relative to the bias of the OLS estimator.

For the case of a single regressor, Staiger and Stock[144] suggest applying the criterion that if the first-stage *F*-statistic, testing the null hypothesis that the instrument set does not significantly predict the endogenous regressor, is less than 10 then the instruments can be thought to be weak. Stock and Yogo[80] extend these ideas to the case where there can be multiple endogenous regressors and propose a test for the null hypothesis that the instruments are weak and provide appropriate critical values. This is an extension of the Cragg and Donald[145] test for instrument relevance. For the case of a single endogenous regressor, the Cragg–Donald statistic is simply the *F*-statistic of the test of the hypothesis that the instruments do not enter the first-stage regression. Stock and Yogo[80] provide critical values of the *F*-statistic (and the Cragg–Donald statistic for multiple endogenous regressors) that tabulates the ratio of 2SLS bias to the bias of OLS. The weakness or otherwise of the instruments can then be assessed by the relative bias exceeding a given threshold (e.g. 2SLS bias exceeding 5% of OLS bias).[q]

To ensure the robustness of our estimates to arbitrary heteroskedasticity, we estimate our models with Stata's -robust- option. The Cragg–Donald statistics are not valid in the presence of heteroskedasticity. We therefore report the Kleibergen–Paap LM statistic (testing instrument relevance) and the Kleibergen–Paap *F*-statistic (testing for weak instruments) which are valid in the presence of heteroskedasticity.

A general test of model specification is provided through the use of Ramsey's[81] reset test for OLS and an adapted version of the test for IVs.[r,81] The tests are more properly thought of as tests of a linearity assumption in the mean function or a test of functional form restrictions and omitted variables[146] and can be useful as a general check of model specification.

Finally, we check that the presumed endogenous variable is in fact endogenous using the test proposed by Durbin.[83] If the null hypothesis of exogeneity cannot be rejected, then we also use the OLS estimator. In addition, although our instruments 'pass' the appropriate statistical tests, some commentators claim that such tests may have 'low power' to detect the presence of invalid instruments. Consequently, in *The sensitivity of the outcome elasticity to the validity of the instrument exclusion restrictions* we examine how sensitive our results are to the relaxation of the assumption that the instruments are valid.

Other estimation issues

In this research we build on previous studies that have used the PB data to estimate the outcome and expenditure models described in *Introduction*. This previous research was undertaken over a period of years and a number of changes were made between these studies (these were sometimes forced on the researchers by, for example, data availability considerations). Here we persevere with the previous approach used to analyse the 2005/6 PB data,[63] but we make some changes to the way in which the 2006/7 (and subsequent) PB data are analysed.

In the next section we start by revisiting the results obtained by Martin *et al.*[63] who used the 2005/6 PB data. In 2005/6 there were 303 PCTs but a series of mergers reduced this total to 152 in 2006/7. These mergers exacerbated greatly the difference in size between the PCTs and so from 2006/7 it makes less sense to give each PCT equal weight in any regression. This is discussed further in *Estimation issues associated with the use of 2006/7 expenditure data* when we come to estimate our model using 2006/7 PB data.

Different PCTs face different costs when buying health-care inputs. For example, some health economy input prices are up to 40% higher in London and the south east of England than elsewhere. In a previous study,[57] we used the MFF index that feeds into the payment by results tariffs for 2007/8 to adjust PB expenditure in 2006/7 for local input prices.[147] This index only reflects costs associated with the purchase of HCHS services but this was the only index available for the new (post-October 2006) set of PCTs at the time of that study. Since then, a more comprehensive set of MFF indices for the 152 PCTs has been published.[74] In *Estimation issues associated with the use of 2006/7 expenditure data* we investigate the use of alternative weighted averages of the HCHS, prescribing, and GMS/PMS MFF indices with weights reflecting the national share of expenditure across these three categories (these weights are 76.3%, 12.4% and 11.3% respectively).[s] For 2005/6, however, we persevere with the MFF employed in the original Martin *et al.* study,[63] namely the HCHS MFF.[148]

Estimation of the expenditure equation for any individual programme requires a proxy for the need for health care across all other programmes. Previous studies of PB expenditure in 2004/5, 2005/6 and 2006/7 have used the circulatory disease mortality rate as a proxy for the need for health care in other programmes in the cancer expenditure equation, and the cancer mortality rate as the proxy for need in other programmes in the circulatory disease expenditure equation.[59,60,63] As these are both programmes that attract considerable expenditure and record considerable mortality, it is not implausible that mortality and expenditure in one of the programmes will impact on expenditure in the other. For other programmes (e.g. respiratory problems and gastrointestinal problems) Martin *et al.*[59,63] used the all-cause mortality rate as a proxy for the 'need in other programmes' variable when analysing expenditure in both 2005/6 and 2006/7. Here, however, we persevere with the previous approach when using 2005/6 PB data but, from 2006/7, in all programmes we proxy the need for health care in other (competing) programmes using the mortality rate in those other programmes (i.e. the all-cause mortality rate minus the own programme mortality rate).

Finally, one data transformation that has been applied in all previous studies and is applied here too is to log-transform all variables so that parameter estimates can be interpreted as elasticities. In other words, a regression coefficient of 0.5 implies that a 1% increase in the regressor is associated with a 0.5% increase in the dependent variable.

Empirical results

Analysis of programme budgeting expenditure for 2005/6 and mortality data for 2002/3/4

This work builds on previous studies. Martin *et al.*[60] reported outcome elasticities for two programmes (cancer and circulatory disease) using expenditure data for 2004/5 and pooled mortality data for 2002, 2003 and 2004. Martin *et al.*[63] extended their preliminary analysis to include several other programmes and, in this extension, they used updated expenditure data (for 2005/6). However, the authors found it difficult to obtain sensible outcome models for some programmes of care. Here we commence our empirical work with an attempt to obtain plausible outcome models for those programmes that defeated Martin *et al.* in their study.[63]

Construction of an alternative measure of need

Our preferred measure of the need for health care is calculated from the Department of Health's PB data set. This data set includes PB expenditure for each care programme as well as the raw population and the 'unified weighted' population for each PCT. The unified weighted population incorporates adjustments to the raw population for both the need for health care as well unavoidable variations in local input costs. The latter are captured via an index which is known as the MFF. By removing the raw population and MFF adjustment from the unified weighted population we are left with the implied level of need, and this is the measure of need that was initially used in the estimation of the model.[63]

The Department of Health PB measure of need associated with expenditure for 2005/6 incorporates the AREA resource allocation formula. This has since been replaced with the CARAN formula and recent work by colleagues at York and the Nuffield Trust has investigated the possibility of constructing a person-based resource allocation (PBRA) measure of need.[149] We therefore decided to investigate the possibility of applying PBRA methods to the construction of an alternative measure of need.

The construction of all of these measures of need involves two steps. The first step requires the estimation of the econometric relationship between the previous utilisation of services and the characteristics of the local areas as existed at the time of the utilisation (e.g. their demographic profile and other indicators of service need such as socioeconomic measures of deprivation). The second step involves the use of this relationship to predict future health-care use given predictions about future demographic characteristics and socioeconomic measures of deprivation.

The major difference between the AREA and CARAN formulae and the PBRA formula is that the former largely use small area-based indicators of socioeconomic characteristics as indicators of the need for health care, whereas the latter largely obviates the requirement for these through the extensive use of individual-based indicators of need. In particular, the PBRA formula employed here is based on an analysis of inpatient and outpatient cost data for 2007/8 for 10% of the entire population of England.[149] As regressors the PBRA utilisation model includes:

(a) 38 age/gender dummies
(b) 150 ICD-10 morbidity markers for each patient reflecting their use of inpatient services in the previous 2 years (that is, in 2005/6 and 2006/7 combined)
(c) four hospital encounter variables for each patient reflecting the intensity of their use of both outpatient and inpatient services in the previous 2 years (that is, in 2005/6 and 2006/7 combined)
(d) 10 small area-based indicators of either local deprivation or health-care supply characteristics; and
(e) 151 PCT dummies (reflecting variations in health-care supply).

The coefficients from this modelling procedure are applied to patient registration data as at 1 April of the year for which the measure of need is required. Here we are studying expenditure in 2005/6 and so we applied the results of the modelling to patient registration data as at 1 April 2005. This requires the construction of a data set containing the patient registration details of all 50 million patients registered

with an English practice at this date. To this we added the patient's age and gender as at 1 April 2005. We also added each patient's ICD-10 morbidity markers and their encounter variables for 2003/4 and 2004/5 combined. Each patient's address [lower super output area (LSOA)] is also added to the data set and this is used to attach the small number of indicators reflecting the LSOA's socioeconomic and health-care supply characteristics.

Given this data set, the calculation of PCT need (given supply) proceeds as follows. First, calculate the national average supply effect. This is the sum of the products of the national average values of the supply variables for the population as at 1 April 2005 and the relevant regression coefficients.

Second, ignore supply and calculate PCT need. This involves calculating the PCT average values of the needs variables by age and gender group for the population as at 1 April 2005. Next, for each PCT, calculate need by age and gender as the sum of the products of the mean values of the needs variables and their respective regression coefficients. Then total PCT need is the sum of need in each age/gender group multiplied by the number of patients in that age/gender group.

Finally, need given supply is calculated as total PCT need plus the number of patients multiplied by the national average supply effect. PCT need per person is simply total PCT need divided by the PCT population. Further details of how to use the results of the PBRA modelling to derive PCT weighted needs indices are presented in Dixon *et al.*[149]

Re-estimation of models using a new measure of need

We re-estimated the outcome and expenditure models for the big four programmes as reported by Martin *et al.*[63] using the new (PBRA-based) measure of need.[t] In summary, the results for the cancer programme were acceptable but not quite as good as previously obtained, and the results for circulation problems, gastrointestinal problems and respiratory problems were poor (e.g. the signs on the expenditure and need variables in the outcome equation were counterintuitive). These were unanticipated results and we were curious to know why our alternative measure of need performed less well than the more established measure.

We undertook a brief comparison of the two measures of need. *Figure 13* provides a scatter plot of the PB and PBRA measures of need. There is a clear positive correlation between the two measures (correlation coefficient = 0.6146), and the summary statistics in *Table 39* suggest that they have similar ranges.

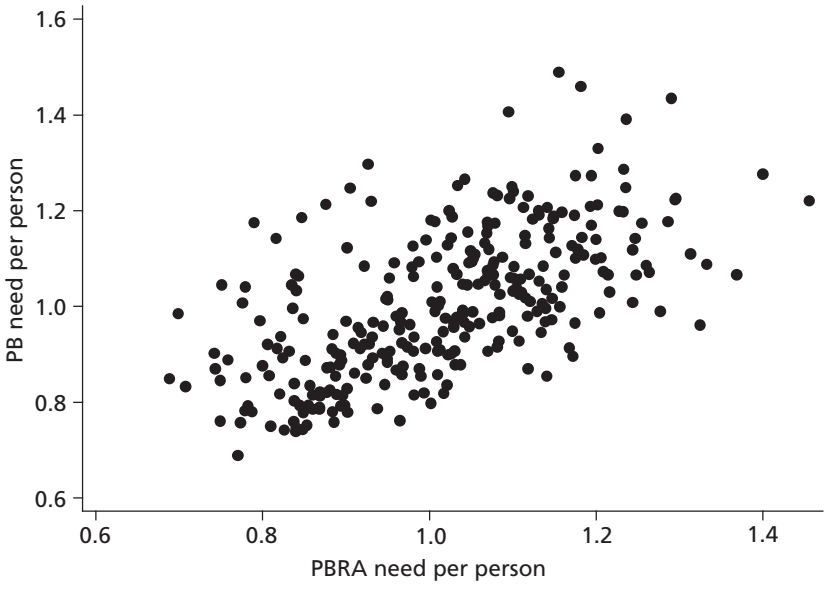


FIGURE 13 Graph showing scatter plot of PB measure of need and PBRA measure of need.

TABLE 39 Table showing summary statistics for PB- and PBRA-based measures of need

Variable	Number of PCTs	Mean	SD	Min.	Max.
PB need	295	1.0062	0.1511	0.6883	1.4889
PBRA need	303	1.0146	0.1448	0.6884	1.4554

Max., maximum; min., minimum; SD, standard deviation.
Note that there are only 295 PCTs with a PB-based measure of need because only 295 of the 303 PCTs were used to estimate our outcome and expenditure models (due to a lack of data for some PCTs).

Table 40 reports values for the PB- and PBRA-based measures of need for selected types of PCTs. These figures suggest that:

- the PBRA measure attributes more need to the least needy areas as defined by the PB measure [see *Table 40*, section (a)]
- the PBRA measure attributes more need to the coastal/retirement areas than does the PB measure [see *Table 40*, section (b)]; and
- the PBRA measure attributes far less need to inner city areas than does the PB measure [see *Table 40*, section (c)].

Although these differences are at first perplexing, they become more understandable when it is noted that the PB and PBRA measures record the level of need across different baskets of services. The PB measure of need refers to all health-care activity, that is, HCHS, prescribing and GMS/PMS (primary care), but the PBRA model only incorporates hospital activity (and it excludes mental health and maternity from this).

The need for hospital-based services is less related to deprivation than are other health-care services. Hence the PBRA measure of need – because it only relates to hospital services – redistributes need away from the more deprived PCTs and towards the more affluent ones. Moreover, expenditure on cancer services is largely hospital based and hence a measure of need based on HCHS spend alone will be reasonably satisfactory for cancer (as indeed we found). However, such a measure of need will perform less well for other programmes (e.g. circulatory disease), where more of the expenditure is on prescribing and/or primary care.

To test these hypotheses we need to compare our PBRA measure of need with a PB measure of need that only relates to acute services (i.e. that excludes maternity and mental health, and all prescribing and GMS/PMS). The Department of Health's measure of need used for the 2005/6 allocations employs the AREA formula for HCHS. This formula does not permit a separation of acute and maternity need and so we cannot compare the PBRA measure of need for 2005/6 with the PB measure for 2005/6 for the same group of specialties (i.e. for acute services excluding maternity and mental health).

However, the CARAN formula, first implemented for the 2009/10 allocations, does distinguish between acute and maternity. But this formula has only been applied to the new (post-October 2006, $n = 152$) PCTs whereas our PBRA-based measure is for the old (pre-October 2006, $n = 303$) PCTs because we are modelling PB expenditure in 2005/6. However, not all of the old PCTs were involved in mergers in October 2006. Thus for about half of all PCTs, we can compare our PBRA-based measure of need for 2005/6 with the CARAN-based measure of need for 2009/10 for the same set of HCHS services (i.e. for acute services excluding maternity and mental health).

The correlation between PBRA need and CARAN acute services need is much higher (correlation coefficient = 0.8722) than that between the PBRA and PB need measures. In addition, an inspection of the values taken by the various need indices (e.g. for acute, maternity, and mental health) for the inner city PCTs (where the PBRA and PB measures of need diverge the most) supports the hypothesis that it is the different

TABLE 40 Table showing values for the PB- and PBRA-based measures of need for selected types of PCT

Area	PB need	PBRA need
(a) Examples of more affluent areas		
Wokingham PCT	0.6883	0.7703
Blackwater Valley and Hart PCT	0.7376	0.8395
Bracknell Forest PCT	0.7410	0.8262
Royston, Buntingford and Bishop's Stortford PCT	0.7426	0.8484
Windsor, Ascot and Maidenhead PCT	0.7460	0.8404
Woking PCT	0.7499	0.8097
Chiltern and South Bucks PCT	0.7515	0.8530
Uttlesford PCT	0.7583	0.8861
North East Oxfordshire PCT	0.7588	0.8372
South Cambridgeshire PCT	0.7619	0.9647
(b) Examples of coastal/retirement areas		
Suffolk Coastal PCT	0.9159	1.0815
Western Sussex PCT	0.9613	1.3248
North Somerset PCT	0.9651	1.1746
Poole PCT	0.9860	1.2045
South and East Dorset PCT	1.0079	1.2439
Fylde PCT	1.0304	1.2157
Southport and Formby PCT	1.0657	1.2141
North Norfolk PCT	1.0658	1.3684
Adur, Arun and Worthing PCT	1.0716	1.2641
East Devon PCT	1.0870	1.3325
(c) Examples of inner city areas		
Brent PCT	0.9848	0.6991
Lambeth PCT	1.0454	0.7512
Islington PCT	1.1222	0.9014
Southwark PCT	1.1412	0.8163
Newham PCT	1.1746	0.7897
City and Hackney PCT	1.1849	0.8472
Bradford City PCT	1.2131	0.8757
Tower Hamlets PCT	1.2192	0.9299
Heart of Birmingham Teaching PCT	1.2466	0.9052
Central Manchester PCT	1.2965	0.9262
Central Liverpool PCT	1.4065	1.0948

service coverage of the PBRA and PB measures of need that explains why they are so poorly correlated (*Table 41*).

For example, the PB index suggests that per capita need in the Newham PCT is 17% *above* the national average, but the PBRA index suggests that it is 21% *below* the national average. We believe that this difference is due to the fact that the PB index relates to all services whereas the PBRA index only relates to acute services. The separate figures for acute, maternity and mental health need from the CARAN formula confirm this hypothesis: CARAN acute need, like PBRA acute need, is well *below* the national average, but maternity and mental health need are well *above* it.

Re-estimation of poorly performing models with an extended instrument set

Martin *et al.*[63] found it difficult to obtain sensible outcome models for some programmes of care. As we were unable to find an improved measure of need, we sought to improve the outcome and expenditure models reported in Martin *et al.*[63] through the use of an extended set of regressors/instruments. Martin *et al.*[63] had focussed on the use of four instruments but here we extend the modelling to include an additional 13 regressors/instruments [born outside EU, LLT, no qualifications, full-time students, no car households, owner occupiers, privately rented, socially rented, lone parents, permanently sick, long-term unemployed, work in agriculture, work in professional occupation]. Further details about these variables can be found in *The threshold changing over time* and precise details about how they were constructed can be found in *Table 92* in the *Annex*.

For each PBC, our modelling strategy with these additional regressors/instruments was the same:

(a) First, estimate an IV model using our preferred set of regressors (with need, budget, and other programme need for the own programme spend model, and with need and spend for the outcome model) and preferred set of instruments (proportion of households that are lone pensioner households, per cent of the population providing unpaid care, the IMD2000, and the per cent of the population in the white ethnic group). Then adjust this set of instruments if necessary (e.g. remove from the instrument set or add an instrument to the regressor set if the Hansen–Sargan test indicates that this is appropriate). Estimate an OLS version of the IV model if the theoretically endogenous regressor is exogenous according to the relevant statistical test.

TABLE 41 Table showing comparing PB, PBRA and CARAN need indexes for selected inner city PCTs

			CARAN need		
PCT	PB need (all services)	PBRA need (acute)	Acute	Maternity	Mental health
City and Hackney PCT	1.1849	0.8472	0.8751	1.6783	1.5340
Tower Hamlets PCT	1.2192	0.9299	0.8451	1.4988	1.6663
Newham PCT	1.1746	0.7897	0.8683	1.8130	1.4486
Haringey PCT	1.0448	0.8347	0.8471	1.4023	1.2886
Brent PCT	0.9848	0.6991	0.8558	1.3420	1.2608
Camden PCT	1.0336	0.8402	0.7667	0.9163	1.3209
Islington PCT	1.1222	0.9014	0.8842	1.1399	1.4516
Lambeth PCT	1.0454	0.7512	0.8111	1.3916	1.3349
Southwark PCT	1.1412	0.8163	0.8445	1.3755	1.3905
Lewisham PCT	1.0402	0.7793	0.8549	1.4253	1.2236
Heart of Birmingham PCT	1.2466	0.9052	0.9078	1.5976	1.5621

(b) Second, if (a) fails to generate a reasonable model, add the same additional variables to both the regressor and instrument sets. Then eliminate insignificant regressors (least significant first, but always retaining, for example, the budget and other need variables in the expenditure model, and own programme spend in the outcome model). Then eliminate insignificant instruments until a reasonable model is obtained. Again, estimate an OLS version of the IV model if the theoretically endogenous regressor is exogenous according to the relevant statistical test.

Instrumental variable estimates of outcome and expenditure models

The above approach generates preferred outcome and expenditure models for each of the programmes with a mortality-based outcome indicator. Outcome models are shown in *Table 42* with expenditure models in *Table 43*. The corresponding first-stage regression results can be found in *Tables 93* and *94*, respectively, in the *Annex*.

The first four results in *Table 42* show the outcome model for the big four programmes (i.e. for cancer, circulatory disease, respiratory problems and gastrointestinal problems). In all four programmes the need variable has a positive and significant effect on mortality, and expenditure has the anticipated negative effect. The diagnostic statistics reveal that, in all four cases, own programme expenditure is endogenous and that the instruments are valid. They also suggest that the instruments are relevant and there is no evidence that the instruments are weak. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

The results for the other programmes are similar to but more diverse than those for the big four programmes. This is to be anticipated because mortality is a much rarer outcome in these programmes than it is in, say, the cancer programme. Own programme expenditure is not endogenous in the next two programmes (infectious diseases and neurological problems) and we revert to the use of the OLS estimator. Expenditure has the anticipated negative effect on mortality in the infectious disease programme, but this is not statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that a measure of need associated with HIV is positively associated with mortality, as is a measure of deprivation (households with no car). Mortality from epilepsy is negatively associated with expenditure in the neurological programme. The need for health-care variables has a positive and significant effect on mortality.

Expenditure and need have the anticipated effects on mortality in the trauma and injuries programme. In addition, the provision of unpaid care appears to be associated with an increase in mortality from fractures. This might be because the availability of care allows the elderly to continue to live in their own home and that they are more likely to fall and die from a fall at home than they are in alternative accommodation (such as in a residential home or sheltered housing).

Expenditure has the anticipated negative effect on mortality in the neonates programme where the generic all service measure of need has been replaced with two more programme-specific indicators of need (the proportion of births that are low birth weight births, and the proportion of households that are lone parent households).

The final two results both employ the OLS estimator. Expenditure in the genitourinary programme has a small negative effect on mortality (from renal problems). The prevalence of one parent households and non-white residents both seem to be positively associated with mortality.

Finally, expenditure has the anticipated negative effect on mortality in the endocrine problems programme where the generic all service measure of need has again been replaced with a more programme-specific indicator of need (the diabetes prevalence rate). Mortality in this programme is also positively associated with the IMD2000.

The first four results in *Table 43* show the expenditure model for the big four programmes (i.e. for cancer, circulatory disease, respiratory problems and gastrointestinal problems). In all four programmes both the

TABLE 42 Table showing preferred outcome models using 2005/6 expenditure data and mortality for 2002/3/4

	2005/6 outcome model, instrument spend, unweighted, second stage				2005/6, outcome model, spend exogenous, unweighted, OLS		2005/6, outcome model, instrument spend, unweighted, second stage		2005/6, outcome model, spend exogenous, unweighted, OLS	
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 1 infectious disease	(6) PBC 7 neurological	(7) PBC 16 trauma	(8) PBC 19 neonates	(9) PBC 17 genitourinary	(10) PBC 4 endocrine
Own programme spend per head	–0.394***	–1.370***	–1.574***	–2.018***	–0.152	–0.182	–1.332***	–0.237*	–0.034	–0.244*
	[0.100]	[0.156]	[0.483]	[0.364]	[0.117]	[0.143]	[0.469]	[0.127]	[0.220]	[0.129]
Need per head	0.905***	2.628***	4.076***	4.254***		1.157***	1.588***			
	[0.083]	[0.163]	[0.562]	[0.412]		[0.252]	[0.445]			
Lone pensioner households			–0.930***							
			[0.158]							
Born outside EU					0.111*					
					[0.063]					
No car households					0.701***					
					[0.114]					
HIV need per head					0.212**					
					[0.082]					
Unpaid carers							1.164***			
							[0.392]			
Low birth weight births								0.919***		
								[0.223]		
Lone parents households								0.549***	1.035***	
								[0.121]	[0.211]	

Variable	2005/6 outcome model, instrument spend, unweighted, second stage				2005/6, outcome model, spend exogenous, unweighted, OLS		2005/6, outcome model, instrument spend, unweighted, second stage		2005/6, outcome model, spend exogenous, unweighted, OLS	
	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 1 infectious disease	(6) PBC 7 neurological	(7) PBC 16 trauma	(8) PBC 19 neonates	(9) PBC 17 genitourinary	(10) PBC 4 endocrine
White ethic group									–1.246***	
									[0.329]	
Population weighted IMD2000										0.421***
										[0.076]
Diabetes prevalence rate 2004/5										14.236***
										[5.195]
Diabetes prevalence rate squared										2.026***
										[0.759]
Constant	4.101***	1.849***	–2.892**	–2.052**	2.654***	0.917**	0.689	1.621***	2.188***	24.258***
	[0.248]	[0.324]	[1.250]	[0.916]	[0.443]	[0.459]	[1.462]	[0.455]	[0.681]	[8.859]
Observations	295	295	295	295	295	294	295	294	267	294
R^2					0.328	0.068			0.169	0.203
Endogeneity test statistic	29.216	65.024	12.630	39.106			3.542	4.071		
Endogeneity *p*-value	6.47e-08	0	0.000380	4.01e-10			0.0598	0.0436		
Hansen–Sargan test statistic	0.786	7.209	1.877	2.468			1.200	5.976		
Hansen–Sargan *p*-value	0.375	0.0655	0.171	0.291			0.273	0.0504		
Shea's partial R^2	0.133	0.311	0.0376	0.173			0.112	0.0735		

continued

TABLE 42 Table showing preferred outcome models using 2005/6 expenditure data and mortality for 2002/3/4 (*continued*)

	2005/6 outcome model, instrument spend, unweighted, second stage				2005/6, outcome model, spend exogenous, unweighted, OLS		2005/6, outcome model, instrument spend, unweighted, second stage		2005/6, outcome model, spend exogenous, unweighted, OLS	
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 1 infectious disease	(6) PBC 7 neurological	(7) PBC 16 trauma	(8) PBC 19 neonates	(9) PBC 17 genitourinary	(10) PBC 4 endocrine
Kleibergen–Paap LM test statistic	26.59	42.31	20.56	34.83			26.97	19.04		
Kleibergen–Paap *p*-value	1.68e-06	1.44e-08	3.44e-05	1.32e-07			1.39e-06	0.000268		
Kleibergen–Paap *F*-statistic	16.94	29.51	10.29	23.32			17.76	11.49		
Pesaran–Taylor reset statistic	0.0347	0.162	0.0929	2.196			0.756	1.388		
Pesaran–Taylor *p*-value	0.852	0.688	0.761	0.138			0.385	0.239		
Ramsey reset *F*-statistic					2.089	0.665			1.075	1.118
Probability > *F*					0.102	0.574			0.360	0.342

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
For the endogeneity test the null hypothesis is that the specified endogenous regressors can actually be treated as exogenous.
The instrument validity test is based on the Hansen–Sargan test. The joint null hypothesis is that the instruments are valid instruments, i.e. uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation.
Shea's partial R^2 is an indicator of the degree of instrument relevance (i.e. of the correlation between the instruments and the endogenous regressor). It is the value of R^2 from a regression of the endogenous variable on the excluded instruments.
A statistical test of instrument relevance is provided by the Kleibergen–Paap LM test. The null hypothesis is that the instruments are not relevant.
Weak identification arises when the excluded instruments are correlated with the endogenous regressor, but only weakly. Estimators can perform poorly when instruments are weak.
The Kleibergen–Paap *F*-statistic provides a formal test of weak identification. The null hypothesis is that the instruments are weak.

TABLE 43 Table showing preferred expenditure models using 2005/6 expenditure data and mortality for 2002/3/4

	2005/6 spend model, instrument other programme need, unweighted, second stage				2005/6 spend model, other programme need exogenous, unweighted, OLS	2005/6 spend model, instrument other programme need, unweighted, second stage		2005/6 spend model, other programme need exogenous, unweighted, OLS			2005/6 spend model, instrument other programme need, unweighted, second stage
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 1 infectious disease	(6) PBC 7 neurological	(7) PBC 16 trauma	(8) PBC 19 neonates	(9) PBC 17 genitourinary	(10) PBC 4 endocrine	(11) PBC 23 GMS/PMS
SYLLR cancer		–0.954***									
		[0.249]									
PCT budget per head	0.968***	0.682***	0.849***	0.772***	0.742***	1.111***	0.627***	0.388	1.041***	0.425**	0.926***
	[0.191]	[0.161]	[0.223]	[0.166]	[0.180]	[0.244]	[0.173]	[0.391]	[0.141]	[0.175]	[0.199]
Need per head	0.703***	0.885***	2.226***	1.115***		0.773***	1.720***			0.570***	
	[0.248]	[0.261]	[0.436]	[0.230]		[0.298]	[0.401]			[0.207]	
White ethnic group		0.198***						–0.739***			
		[0.066]						[0.181]			
Provision of unpaid care		0.364***					–0.339*				
		[0.136]					[0.190]				
SYLLR circulatory disease	–0.577***										
	[0.107]										
Lone pensioners			–0.612***								–0.257**
			[0.165]								[0.101]
SYLLR all deaths			–1.367***	–0.639***	–0.437***	–0.899***	–1.157***	0.121	0.035	–0.158	–1.003***
			[0.328]	[0.149]	[0.157]	[0.182]	[0.274]	[0.307]	[0.099]	[0.116]	[0.276]

continued

TABLE 43 Table showing preferred expenditure models using 2005/6 expenditure data and mortality for 2002/3/4 (*continued*)

	2005/6 spend model, instrument other programme need, unweighted, second stage				2005/6 spend model, other programme need exogenous, unweighted, OLS	2005/6 spend model, instrument other programme need, unweighted, second stage		2005/6 spend model, other programme need exogenous, unweighted, OLS			2005/6 spend model, instrument other programme need, unweighted, second stage
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 1 infectious disease	(6) PBC 7 neurological	(7) PBC 16 trauma	(8) PBC 19 neonates	(9) PBC 17 genitourinary	(10) PBC 4 endocrine	(11) PBC 23 GMS/PMS
Born outside EU					0.069**						
					[0.029]						
Full-time students					–0.165***				0.127***		
					[0.053]				[0.031]		
No car households					0.444***						
					[0.099]						
HIV need per head					0.142***						
					[0.034]						
London boroughs dummy					0.942***						
					[0.106]						
LA/HA rented housing								0.377***			
								[0.126]			
No qualifications											0.521***
											[0.140]
Private rented housing											0.102**
											[0.041]

Variable	2005/6 spend model, instrument other programme need, unweighted, second stage				2005/6 spend model, other programme need exogenous, unweighted, OLS	2005/6 spend model, instrument other programme need, unweighted, second stage		2005/6 spend model, other programme need exogenous, unweighted, OLS			2005/6 spend model, instrument other programme need, unweighted, second stage
	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 1 infectious disease	(6) PBC 7 neurological	(7) PBC 16 trauma	(8) PBC 19 neonates	(9) PBC 17 genitourinary	(10) PBC 4 endocrine	(11) PBC 23 GMS/PMS
Work in agriculture											–0.058***
											[0.022]
Constant	–0.020	3.440***	4.368**	1.241	–0.969	2.066*	3.631**	–4.760**	–2.854***	–2.435***	4.320**
	[0.517]	[1.111]	[1.757]	[0.930]	[1.037]	[1.131]	[1.414]	[1.920]	[0.604]	[0.726]	[1.703]
Observations	295	295	295	295	295	295	295	295	295	295	295
Endogeneity test statistic	6.465	12.921	19.325	7.218		13.865	12.690				5.273
Endogeneity *p*-value	0.0110	0.000325	1.10e-05	0.00722		0.000196	0.000368				0.0217
Hansen–Sargan test statistic	0.416	1.925	0.00232	2.441		0.826	3.577				3.213
Hansen–Sargan *p*-value	0.519	0.165	0.962	0.118		0.662	0.0586				0.201
Shea's partial R^2	0.450	0.141	0.168	0.416		0.450	0.239				0.290
Kleibergen–Paap LM test statistic	63.99	31.27	33.11	57.16		64.15	39.80				47.98
Kleibergen–Paap *p*-value	0	1.62e-07	6.47e-08	0		0	2.28e-09				2.15e-10
Kleibergen–Paap *F*-statistic	109.7	21.74	19.08	98.29		70.14	40.01				43.10

continued

TABLE 43 Table showing preferred expenditure models using 2005/6 expenditure data and mortality for 2002/3/4 (*continued*)

	2005/6 spend model, instrument other programme need, unweighted, second stage				2005/6 spend model, other programme need exogenous, unweighted, OLS	2005/6 spend model, instrument other programme need, unweighted, second stage		2005/6 spend model, other programme need exogenous, unweighted, OLS			2005/6 spend model, instrument other programme need, unweighted, second stage
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 1 infectious disease	(6) PBC 7 neurological	(7) PBC 16 trauma	(8) PBC 19 neonates	(9) PBC 17 genitourinary	(10) PBC 4 endocrine	(11) PBC 23 GMS/PMS
Pesaran–Taylor reset statistic	2.679	0.231	0.848	0.987		0.0184	0.912				0.668
Pesaran–Taylor *p*-value	0.102	0.631	0.357	0.320		0.892	0.340				0.414
R^2					0.709			0.177	0.399	0.267	
Ramsey reset *F*-statistic					1.572			0.250	1.358	0.765	
Probability > *F*					0.196			0.861	0.256	0.514	

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
For the endogeneity test the null hypothesis is that the specified endogenous regressors can actually be treated as exogenous.
The instrument validity test is based on the Hansen–Sargan test. The joint null hypothesis is that the instruments are valid instruments, i.e. uncorrelated with the error term, and that the excluded instruments are correctly excluded from the estimated equation.
Shea's partial R^2 is an indicator of the degree of instrument relevance (i.e. of the correlation between the instruments and the endogenous regressor). It is the value of R^2 from a regression of the endogenous variable on the excluded instruments.
A statistical test of instrument relevance is provided by the Kleibergen–Paap LM test. The null hypothesis is that the instruments are not relevant.
Weak identification arises when the excluded instruments are correlated with the endogenous regressor, but only weakly. Estimators can perform poorly when instruments are weak.
The Kleibergen–Paap *F*-statistic provides a formal test of weak identification. The null hypothesis is that the instruments are weak.

need and budget variables have a positive and significant effect on own programme expenditure. In addition, the proxy for need in other programmes is negative and significant in all four cases. In the circulatory expenditure programme the provision of unpaid care is associated with more expenditure (patients may buy care in more affluent areas), as is the proportion of residents in the white ethnic group (there might be some unmet need associated with circulatory problems in the non-white ethnic groups).

The PCT budget variable is positive in all of the remaining seven programmes and this variable is significant in six of the seven. The proxy for other programme need (SYLLR all deaths) has the anticipated negative sign in five of the seven programmes and, where it is positive, it is never statistically significant.

The all service proxy for own programme need is positive and significant in three programmes. In the other four programmes, however, it has been replaced by various other socioeconomic indicators of need (in the trauma programme, for example, the provision of unpaid care is associated with a reduction in NHS expenditure and, in the neonates programme, the proportion of residents in the white ethnic group is negatively associated with expenditure).

The diagnostic statistics reveal that, for all seven IV models, expenditure is endogenous and the instruments are valid. They also suggest that the instruments are relevant and there is no evidence that the instruments are weak. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

Instrumental variable estimates of outcome and expenditure models: the first-stage equations

For the health outcome equation, IV estimation involves finding variables (instruments) that are good predictors of programme expenditure but which are appropriately excluded from the equation of interest (that is, from the outcome equation). The assumption is that the instruments impact on the health outcome through their impact on expenditure only, and that they do not have a direct effect on the outcome. If, on the other hand, an instrument reflects unobserved factors that affect both expenditure and mortality directly, then the IV estimator becomes both biased and inconsistent. Such an instrument is said to be 'invalid' because it belongs in the equation of interest in its own right.

In our outcome model we typically employ two instruments (call these $z1$ and $z2$) for expenditure. IV estimation assumes that these instruments do not belong in the outcome equation. In other words, IV estimation assumes that the coefficients $\gamma 1$ and $\gamma 2$ in the outcome model:

$$y = \alpha + \beta 1x + \beta 2n + \gamma 1z1 + \gamma 2z2 + \varepsilon, \tag{14}$$

are identically zero (where y is mortality, x is expenditure, and n is a measure of the own programme need for health care and all variables relate to a particular programme of care). Such exclusion restrictions can be debatable and researchers who employ IV techniques often devote considerable effort towards convincing the reader that their assumed exclusion restrictions are a good approximation.[88,89] These efforts usually take two forms: first, researchers often offer a strong theoretical economic argument why their instruments do not belong in the equation of interest; and second, statistical tests for the validity of the exclusion restrictions (Sargan 2SLS, Hansen J-test generalised method of moments) are routinely reported as part of the results for any study that employs IV techniques.

It is difficult for us to identify clear theoretical reasons why our instruments (such as the proportion of lone pensioner households, the provision of unpaid care and an index of multiple deprivation) do not belong in the equation of interest (that is, that they will not *directly* affect mortality). Of necessity, therefore, we must be guided by the available statistical tests for the validity of the exclusion restrictions. However, although our outcome models 'pass' the relevant statistical test, some commentators have argued that the Sargan–Hansen test may have weak power and may fail to reject the null hypothesis of instrument validity even when an exclusion restriction is not valid. As we shall see in *The sensitivity of the outcome elasticity*

to the validity of the instrument exclusion restrictions, this is likely to be the case when the induced biases in the estimates of β1 (the coefficient on the endogenous variable) are the same across all instruments. The Hansen–Sargan J-test statistic will be small when the null hypothesis of valid instruments is correct; but it will also be small if the biases induced in $\widehat{\beta}1$ by invalid instruments all coincide (i.e. the instruments all identify the *same* wrong parameter).[150] In other words, for the Hansen–Sargan J test to have low power the use of any subset of instruments should generate the *same* asymptotic bias in $\widehat{\beta}1$.

Our approach, implemented below, is to identify theoretical reasons why our instruments might belong in the first-stage expenditure equation but not in the second-stage outcome equation. Even if our arguments are thought unconvincing, a critic would also have to argue that any subset of our selected instruments will each induce the same bias in the coefficient on the endogenous variable. This is because it is only in these circumstances that the Hansen–Sargan test will be unable to reject the null hypothesis of instrument validity even when an exclusion restriction is not valid.

The first-stage regressions associated with the IV outcome results in *Table 42* can be found in *Table 93* in the *Annex*. A brief summary of the first-stage regressions is provided below.

Cancer programme of care

The instrument set for the cancer programme of care [see column (1) in *Table 93*] includes the proportion of households that are lone pensioner households and the proportion of the population providing unpaid care. These instruments have intuitive appeal. The first-stage regression of cancer expenditure on the instruments and the need for health care (as an exogenous regressor in the 2SLS model) reveals a positive and significant coefficient on lone pensioners and a negative but non-significant coefficient on the proportion of unpaid carers. The proportion of lone pensioners is likely to reflect an additional adjustment for health-care need specific to an elderly and needy population. The omission of this variable from the second-stage regression is plausible as the dependent variable relates to mortality under 75 years of age and some of the lone pensioners will be aged over 75 years, and members of this group are, by definition, relatively healthy individuals. Unpaid care might act as a substitute for the provision of health-care services and, in these circumstances, a negative relationship with expenditure is to be expected. There is no obvious relationship between the provision of unpaid care and mortality.

Circulatory disease programme of care

The two instruments used for cancer were also employed to predict expenditure in the circulatory disease programme and they were augmented with the addition of the population weighted index of multiple deprivation (IMD2000). The relevance of the latter variable is theoretically plausible as circulatory disease is more related to disadvantage than is cancer. In addition, we also employed the proportion of residents in the white ethnic group as an additional instrument for expenditure, but its coefficient is very small and it is not statistically significant.

Increased expenditure on circulatory disease in the first-stage regression is associated with a greater proportion of pensioners living alone and a greater proportion of unpaid carers. The latter may reflect an increased awareness and compliance with medical intervention, particularly preventative measures, brought about by carers, but this will not affect our outcome model if the impact of this additional support is largely on the mortality of those aged > 75 years. Expenditure on circulatory problems is also negatively associated with the IMD2000. As the IMD incorporates an access to medical services domain, this negative association might reflect some unmet need which largely affects mortality in those aged > 75 years.

Respiratory problems programme of care

The IMD2000 is negatively associated with expenditure on respiratory problems. As the IMD incorporates an access to medical services domain, this negative association might reflect some unmet need which largely affects mortality in those aged > 75 years. The proportion of the population aged 16–74 years that is permanently sick has a positive association with expenditure but might not affect mortality in those aged < 75 years if expenditure is largely directed towards managing chronic disease.

Gastrointestinal problems programme of care

Increased expenditure on gastrointestinal problems in the first-stage regression is positively associated with the proportion of residents providing unpaid care. This may reflect an increased awareness and compliance with medical intervention, particularly preventative measures, brought about by carers, but this will not affect our outcome model if the impact of this additional support is largely on the mortality of those aged > 75 years.

Trauma, burns and injuries programme of care

Increased expenditure on trauma, burns and injuries in the first-stage regression is positively associated with the proportion of pensioners living alone. This may reflect longer stays in hospital and an increased need for community care. However, the proportion of pensioners living alone will have little effect on our mortality measure if most of this expenditure is associated with patients > 75 years of age.

Neonate programme of care

The percentage of those aged 16–74 years that are long-term unemployed and the proportion of households that are in social rented housing are both positively associated with expenditure on neonate care. These are both indicators of socioeconomic deprivation and might be associated with the presence of larger families (i.e. more children per family). This would affect expenditure per head of population but not necessarily mortality per 1000 live births. The negative coefficient on the proportion of those aged 16–74 years with no qualifications might reflect the 'emigration' of young adults from those areas that are particularly deprived. This would reduce expenditure per head of population but would have no impact on the mortality measure.

The first-stage regressions associated with the IV expenditure results in *Table 43* can be found in *Table 94* in the *Annex*.

Cancer programme of care

The first-stage equation for the cancer expenditure model includes two instruments – lone pensioners and unpaid carers – that are excluded as regressors from the second stage of estimation. In this model the first-stage regression of other programme need (as proxied here by the circulatory disease mortality rate) on the instrument set generates a negative coefficient on both instruments excluded from the second-stage regression. A greater proportion of unpaid carers might reflect an increased level of care (and perhaps increased compliance with care programmes and drug regimes) resulting in a decrease in other programme deaths. The availability of unpaid care in the community might not have a direct effect on cancer expenditure if such care supplements rather than substitutes for NHS-funded care. Conditional on need and the total PCT budget, the negative coefficient on the proportion of lone pensioners may be indicative of the presence of increased networks of social support. If this additional support reduces other programme mortality but does not substitute for NHS care, then the lone pensioner variable will not belong in the expenditure equation.

Circulatory disease programme of care

In the circulatory disease expenditure model, the first-stage regression of other programme need (as proxied here by the cancer mortality rate) on the instrument set results in a negative coefficient on one instrument (lone pensioners) and a positive coefficient on the other (the IMD2000). As noted above, the negative coefficient on the proportion of lone pensioners may be indicative of areas with increased networks of social support. If this additional support does not substitute for NHS care then the lone pensioner variable will not belong in the expenditure equation. It is plausible that the IMD2000 should have a positive effect on other programme need but not belong in the expenditure equation if, for example, there is some unmet need in another (but not the circulatory disease) care programme.

Respiratory problems programme of care

In the respiratory disease expenditure model, the first-stage regression of other programme need (as proxied here by the all cause SYLLR) on the instrument set results in a negative coefficient on one instrument (unpaid care) and a positive coefficient on another (the IMD2000). A greater proportion of unpaid carers might reflect an increased level of care (and perhaps increased compliance with care programmes and drug regimes) resulting in a decrease in other programme deaths. The availability of unpaid care might not have a direct effect on own programme expenditure if such care does not substitute for NHS-funded care. It is plausible that the IMD2000 should have a positive effect on other programme need but not belong in the expenditure equation if, for example, there is some unmet need in another (but not the respiratory disease) care programme.

Gastrointestinal problems programme of care

In the gastrointestinal problems expenditure model, the first-stage regression of other programme need (as proxied here by the all cause SYLLR) on the instrument set (including need and total budget) results in a negative coefficient on one instrument (lone pensioners) and a positive coefficient on the other (IMD2000). As noted above, the negative coefficient on the proportion of lone pensioners may be indicative of areas with increased networks of social support. If this additional support does not substitute for NHS care then the lone pensioner variable will not belong in the expenditure equation. It is plausible that the IMD2000 should have a positive effect on other programme need but not belong in the expenditure equation if, for example, there is some unmet need in another (but not the gastrointestinal) care programme.

Neurological problems programme of care

The first-stage equation for the neurological expenditure model includes three instruments – lone pensioners, unpaid carers and IMD2000 – that are excluded as regressors from the second stage of estimation. Explanations for the signs on these variables have been outlined above when discussing the other first-stage regressions.

Trauma and injuries programme of care

The first-stage equation for the trauma expenditure model includes two instruments – lone pensioners and the IMD2000 – that are excluded as regressors from the second stage of estimation. Explanations for the signs on these variables have been outlined above when discussing the other first-stage regressions.

General medical services/primary medical services programme of care

The first-stage equation for the GMS/PMS expenditure model includes three instruments – households with no car, lone parents and permanently sick – that are excluded as regressors from the second stage of estimation. All three are plausibly positively associated with other programme need (as proxied here by the all cause SYLLR) but do not occur as regressors in the second-stage GMS/PMS expenditure model. The latter includes at least one measure of deprivation – the proportion of people aged 16–74 years without any qualifications – and the Hansen–Sargan test suggests that the three excluded instruments offer no additional explanatory power for observed variations in GMS/PMS expenditure.

We appreciate that not everyone will be convinced by our arguments about the validity of our instruments and so in *The sensitivity of the outcome elasticity to the validity of the instrument exclusion restrictions* we undertake a sensitivity analysis that examines the impact of weakening the instrument exclusion restriction.

Calculation of the cost of a life and life-year

The preferred models identified in *Tables 42* and *43* indicate the responsiveness of mortality to changes in expenditure, and of own programme expenditure to changes in budget, using expenditure data for 2005/6. Together with information about programme expenditure and mortality, the coefficients on the own programme expenditure and PCT budget variables listed in *Tables 42* and *43* can be used to calculate the cost of an additional life-year for the 10 programmes for which outcome and expenditure models are available.[u] For a relatively small budget change:

the cost of an additional life in a particular programme
= the change in expenditure in that programme/the change in mortality in that programme
= (annual spend × expenditure elasticity)/(annual mortality × outcome elasticity × expenditure elasticity)

and

the cost of an additional life-year in a particular programme
= the change in expenditure in that programme/the change in life-year lost in that programme
= (annual spend × expenditure elasticity)/(annual life-year lost × outcome elasticity
× expenditure elasticity).

Table 44 presents the necessary information to calculate the cost of an additional life (or life-year) for each of these 10 programmes. There is an assumed small (1%) increase in the national budget and it is also assumed that this increase is applied to each PCT's budget. The total additional spend in each programme associated with this injection [see *Table 44*, column (D)] is determined by the initial level of expenditure in the programme [see *Table 44*, column (B)] and the programme's expenditure elasticity [see *Table 44*, column (C)]. In addition, this additional spend, in conjunction with the outcome elasticity (column F) and the number of deaths in the programme [see *Table 44*, column (E)], determine the number of lives saved that is associated with the additional expenditure. If we divide the change in programme expenditure [see *Table 44*, column (D)] by the change in the number of lives lost [see *Table 44*, column (G)] we obtain the cost per life gained [see *Table 44*, column (H)].

Alternatively, we can apply the outcome elasticity [see *Table 44*, column (F)] to the annual number of life-years lost in the programme [see *Table 44*, column (E)] to determine the number of life-years saved that is associated with the additional expenditure. If we divide the change in programme expenditure [see *Table 44*, column (D)] by the change in the number of life-years lost [see *Table 44*, column (J)] we obtain the cost per YLG [see *Table 44*, column (K)]. Note that none of these figures are QALY adjusted and that all costs are at current (2005/6) prices.

The cost per life-year associated with the cancer programme is £13,741 and this is almost identical to that calculated using expenditure data for 2004/5, but with the same mortality data as that employed here.[60] Similarly, the cost per life-year associated with the circulatory disease programme is £8328 and this is also almost identical to that calculated using expenditure data for 2004/5 but with the same mortality data as that employed here.[60] The cost per life-year for the respiratory programme (£20,601) and for the gastrointestinal programme (£18,303) are a little larger than these figures but are still of the same order of magnitude. Taken together, the cost per life-year for these 'big four PBCs' is £12,855.[v,w]

Table 44 also contains cost per life-year estimates for the six other programmes for which a mortality-based outcome indicator is available. These cost estimates are much larger than those for the big four programmes. This is to be expected as mortality is a less relevant outcome indicator for these PBCs than for the big four programmes. The cost per life-year across all 10 programmes for which a mortality-based outcome indicator is available is £21,256.

Although we have an estimate of the cost per life-year for 10 programmes, it is unclear how we should adjust this estimate for the expenditure associated with the other 13 programmes. We attempted to estimate an outcome and expenditure model for expenditure and mortality in all 13 of these programmes combined.[x] However, this was not successful with, for example, counterintuitive signs on some variables.[y]

TABLE 44 Table showing cost of life and life-year estimates for 2005/6 for the 10 programmes for which we have outcome and expenditure elasticities

PBC scenario	(A) PBC description	(B) Spend (£M) 2005/6	(C) Spend elasticity	(D) (= 0.01 × B × C) change in spend (£M)	(E) Annual mortality, < 75 years, 2002/3/4	(F) Outcome elasticity	(G) (= 0.01 × C × E × F) change in annual mortality	(H)(= D/G) cost per life gained (£)	(I) Total life-years lost, < 75 years, 2002/3/4	(J) (= 0.01 × C × F × I/3) change in annual life-years lost	(K) (= D/J) cost per YLG (£)
1	Cancer	4094	0.968	39.63	62,259	0.394	237.45	166,897	2,268,541	2884	13,741
2	Circulatory problems	6112	0.682	41.68	45,504	1.370	425.16	98,042	1,607,171	5005	8328
3	Respiratory problems	3421	0.849	29.04	11,601	1.574	155.03	187,350	316,506	1410	20,601
4	Gastrointestinal problems	3998	0.772	30.86	5926	2.018	92.32	334,318	324,735	1686	18,303
5	Big four programmes	17,625		141.22	125,290		909.96	155,196	4,516,953	10,986	12,855
6	Infectious diseases	1161	0.742	8.61	2050	0.152	2.31	3,725,931	106,552	40	215,054
7	Endocrine problems	1832	0.425	7.79	1690	0.244	1.75	4,442,720	60,615	21	371,601
8	Neurological problems	2019	1.111	22.43	729	0.182	1.47	15,217,293	66,137	45	503,201
9	Genitourinary problems	3313	1.041	34.49	294	0.034	0.10	331,432,573	10,030	1	29,144,918
10	Trauma and injuries	3758	0.627	23.56	1037	1.332	8.66	2,720,657	30,000	84	282,132
11	Neonate conditions	660	0.388	2.56	2123	0.237	1.95	1,311,733	477,675	146	17,490
12	All 10 programmes	30,368	0.792	240.67	133,213		926.22	259,838	5,267,962	11,322	21,256

Instead, we decided to make some assumptions about the cost per life-year associated with the other 13 programmes. We examined two possibilities. First, we assumed that the other 13 programmes generate no mortality gain at all. This is clearly unrealistic but it does provide an upper bound for the cost per life-year across all programmes of care. *Table 45* is similar to *Table 44* but it incorporates this zero gain assumption for the 13 other programmes.[z] It shows that the cost per life-year across all 23 programmes – assuming a zero mortality gain in the 13 programmes without a mortality based indicator – is £56,799.

Second, the zero mortality gain assumption is an extreme one but possibly relevant for the residual programme (PBC 23) – where about two-thirds of the expenditure is attributable to primary care – if we assume that any mortality gain associated with primary care expenditure is reflected in mortality rates associated with other, more disease-specific, programmes (e.g. cancer, circulatory disease, etc.). However, if we assume a zero mortality gain in PBC 23, what assumption should we make about the mortality gain associated with the remaining 12 programmes?

One possibility is to assume that the cost per life (year) in the remaining 12 programmes is on average the same as that associated with the 10 programmes for which a mortality-based outcome indicator is available. At first this may sound strange as we have already noted that mortality is not regularly associated with these programmes whereas it is a normal outcome for the 10 programmes for which a mortality-based outcome indicator is available (and this is of course why mortality data at PCT level is available for these 10 PBCs). However, if we broaden our interpretation of health gain to include non-mortality effects (such as those on the QoL), then this assumption – that the cost per life (year) in the remaining 12 programmes is on average the same as that associated with the 10 programmes for which a mortality-based outcome indicator is available – becomes far more plausible.

Thus, *Table 46* is similar to *Table 45* but incorporates (a) a zero gain assumption for the residual (including primary care) programme (PBC 23); and (b) an average gain assumption for the remaining 12 programmes for which no mortality-based outcome indicator is available. *Table 46* shows that the cost per life-year across all 23 programmes [see *Table 46*, row (15)] is £24,200. This is, of course, slightly greater than the cost of a life-year for the 10 programmes for which a mortality-based outcome indicator is available (£21,256) because a small proportion of expenditure (that on primary care) is assumed to have no health benefit beyond that captured by the more disease-specific programmes (e.g. in cancer, circulatory disease, etc.).

The costs quoted in *Tables 44–46* make no QALY adjustment but such an adjustment would add between 50% and 66% to the costs quoted.[100]

TABLE 45 Table showing cost of life and life-year estimates for 2005/6 for all programmes (assumes that 13 PBCs offer no health gain)

PBC scenario	(A) PBC description	(B) Spend (£M) 2005/6	(C) Spend elasticity	(D) (= 0.01 × B × C) change in spend (£M)	(E) Annual mortality, < 75 years, 2002/3/4	(F) Outcome elasticity	(G) (= 0.01 × C × E × F) change in annual mortality	(H) (= D/G) cost per life gained (£)	(I) Total life-years lost, < 75 years, 2002/3/4	(J) (= 0.01 × C × F × I/3) change in annual life-years lost	(K) (= D/J) cost per YLG (£)
1	Cancer	4094	0.968	39.63	62,259	0.394	237.45	166,897	2,268,541	2884	13,741
2	Circulatory problems	6112	0.682	41.68	45,504	1.370	425.16	98,042	1,607,171	5005	8328
3	Respiratory problems	3421	0.849	29.04	11,601	1.574	155.03	187,350	316,506	1410	20,601
4	Gastrointestinal problems	3998	0.772	30.86	5926	2.018	92.32	334,318	324,735	1686	18,303
5	Big four programmes	17,625		141.22	125,290		909.96	155,196	4,516,953	10,986	12,855
6	Infectious diseases	1161	0.742	8.61	2050	0.152	2.31	3,725,931	106,552	40	215,054
7	Endocrine problems	1832	0.425	7.79	1690	0.244	1.75	4,442,720	60,615	21	371,601
8	Neurological problems	2019	1.111	22.43	729	0.182	1.47	15,217,293	66,137	45	503,201
9	Genitourinary problems	3313	1.041	34.49	294	0.034	0.10	331,432,573	10,030	1	29,144,918
10	Trauma and injuries	3758	0.627	23.56	1037	1.332	8.66	2,720,657	30,000	84	282,132
11	Neonate conditions	660	0.388	2.56	2123	0.237	1.95	1,311,733	477,675	146	17,490
12	All 10 programmes	30,368	0.792	240.67	133,213		926.22	259,838	5,267,962	11,322	21,256
13	Assume no health gain	33,942		402.43			0.00			0	
14	All 23 programmes	64,310		643.10			926.22	694,330		11,322	56,799

TABLE 46 Table showing cost of life and life-year estimates for 2005/6 for all programmes (assumes GMS/PMS provides no gain, other PBCs provide average gain)

PBC scenario	(A) PBC description	(B) Spend (£M) 2005/6	(C) Spend elasticity	(D) (= 0.01 × B × C) change in spend (£M)	(E) Annual mortality, < 75 years, 2002/3/4	(F) Outcome elasticity	(G) (= 0.01 × C × E × F) change in annual mortality	(H) (= D/G) cost per life gained (£)	(I) Total life-years lost, < 75 years, 2002/3/4	(J) (= 0.01 × C × F × I/3) change in annual life-years lost	(K) (= D/J) cost per YLG (£)
1	Cancer	4094	0.968	39.63	62,259	0.394	237.45	166,897	2,268,541	2884	13,741
2	Circulatory problems	6112	0.682	41.68	45,504	1.370	425.16	98,042	1,607,171	5005	8328
3	Respiratory problems	3421	0.849	29.04	11,601	1.574	155.03	187,350	316,506	1410	20,601
4	Gastrointestinal problems	3998	0.772	30.86	5926	2.018	92.32	334,318	324,735	1686	18,303
5	Big four programmes	17,625		141.22	125,290		909.96	155,196	4,516,953	10,986	12,855
6	Infectious diseases	1161	0.742	8.61	2050	0.152	2.31	3,725,931	106,552	40	215,054
7	Endocrine problems	1832	0.425	7.79	1690	0.244	1.75	4,442,720	60,615	21	371,601
8	Neurological problems	2019	1.111	22.43	729	0.182	1.47	15,217,293	66,137	45	503,201
9	Genitourinary problems	3313	1.041	34.49	294	0.034	0.10	331,432,573	10,030	1	29,144,918
10	Trauma and injuries	3758	0.627	23.56	1037	1.332	8.66	2,720,657	30,000	84	282,132
11	Neonate conditions	660	0.388	2.56	2123	0.237	1.95	1,311,733	477,675	146	17,490
12	All 10 programmes	30,368	0.792	240.67	133,213		926.22	259,838	5,267,962	11,322	21,256
13	(a) Assume no health gain for GMS/PMS	8449	0.926	78.24			0.00			0	
14	(b) Assume average gain in the other 12 PBCs	25,493	1.272	324.20			1247.69	259,838		15,252	21,256
15	All 23 programmes	64,310		643.10			2173.90	295,827		26,575	24,200

Summary and conclusion

In this section we have extended the results reported by Martin *et al.*[63] by obtaining plausible outcome and expenditure models for all 10 programmes of care with a mortality-based outcome indicator. In addition, we have, for the first time, calculated the cost of a life-year across the big four programmes combined (£12,855) and across all 10 programmes (£21,256). Moreover, with the aid of an assumption about the productivity (health gain) of programmes without a meaningful mortality-based outcome indicator, we have extended our individual programme estimates to incorporate expenditure across all programmes of care.

If we assume that the other 13 programmes without a mortality-based outcome indicator generate no health gain then the cost of an additional life-year across all expenditure for 2005/6 is £56,799.

Alternatively, if we assume that any health-care gain associated with primary care expenditure is reflected in mortality rates associated with other, more disease-specific programmes, and that the health gain associated with the remaining 12 programmes is, on average, the same as that recorded by the PBCs with a mortality-based indicator, then the cost per life-year across all expenditure for 2005/6 is £24,200.

This concludes our analysis of the 2005/6 PB data. In the next section we apply our model to the 2006/7 PB data.

Analysis of programme budgeting expenditure for 2006/7

Construction of an alternative measure of need

The analysis of the 2005/6 PB data employed a measure of the need for health care that incorporated the AREA resource allocation formula for acute services. As was described in *Instrumental variable estimation*, we attempted to construct a better measure of need using a recently developed person-based approach.[149] However, we were unable to construct a viable alternative PBRA-based measure of need for use with the PB data for 2005/6 because the PBRA formula only relates to acute services yet the PB data incorporates elements for acute, maternity, mental health, prescribing and primary care, and we were unable to separate these component parts.

The construction of an alternative measure of need is, however, possible for use with the 2006/7 PB data. Spend and mortality data are available for the new (152) PCTs, and the Department of Health's resource allocation exposition book for 2009/10 (which employs the CARAN model) provides separate measures of need for acute, maternity, mental health, prescribing and GMS/PMS services. We can therefore replace the (CARAN-based) measure of acute need for the 2009/10 allocation with our own PBRA-based measure of acute need (albeit for 2006/7) to calculate an alternative to the AREA-based measure of need across all health-care services.

The PBRA model was applied to all patients on practice lists as at 1 April 2006 to generate a PCT-level measure of acute need (see *Construction of an alternative measure of need* for a description of this approach as applied to patients on practice lists as at 1 April 2005). The resulting PBRA measure of acute need can be compared with the CARAN-based measure of acute need as reported in the Department of Health's resource allocation exposition book for 2009/10. The correlation coefficient for these two measures is 0.8514 and descriptive statistics for the two measures are shown below in *Table 47*.

The all service measure of need (which is a weighted average of the acute, maternity, mental health, prescribing and GMS/PMS measures) as reported in the Department of Health's resource allocation exposition book for 2009/10 can be recalculated by replacing the CARAN-based acute measure with the PBRA-based acute measure of need. The correlation coefficient for these two all service measures of need is 0.9714 and *Figure 14* shows a scatter plot of these two measures. Descriptive statistics for these two all service measures of need along with the (AREA-based) PB measure of need are shown in *Table 48*.

The correlation coefficients for the three measures are shown in *Table 49*.

TABLE 47 Table showing summary statistics for the CARAN- and PBRA-based measures of acute need

Variable	Number of PCTs	Mean	SD	Min.	Max.
CARAN_acute need	152	1.0033	0.1113	0.7659	1.2153
PBRA_acute need	152	1.0037	0.1218	0.7606	1.3420

Max., maximum; min., minimum; SD, standard deviation.

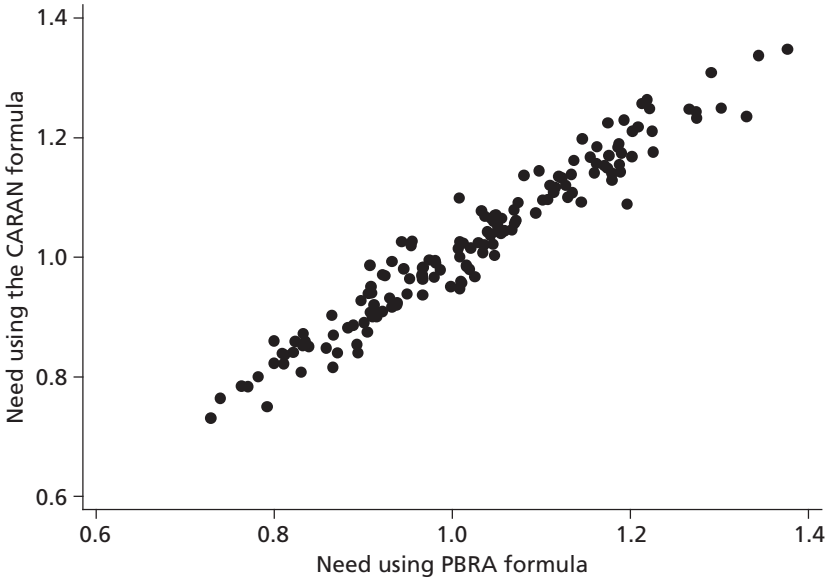


FIGURE 14 Graph showing scatter plot of all service measures of need: incorporating CARAN- or PBRA-based measures of acute need.

TABLE 48 Table showing all service measures of need: incorporating CARAN-, PBRA- or AREA-based measures of acute need

Variable	Observations	Mean	SD	Min.	Max.
PCTneed_CARAN	152	1.0240	0.1339	0.7311	1.3479
PCTneed_PBRA	152	1.0242	0.1395	0.7287	1.3769
PCTneed_AREA	152	1.0293	0.1380	0.7165	1.4006

Max., maximum; min., minimum; SD, standard deviation.

TABLE 49 Table showing correlation coefficients for alternative measures of all service need

Variable	PCTneed_AREA	PCTneed_PBRA	PCTneed_CARAN
PCTneed_AREA	1		
PCTneed_PBRA	0.9583	1	
PCTneed_CARAN	0.9839	0.9714	1

Estimation issues associated with the use of 2006/7 expenditure data

As well as having to select a preferred measure of need from the three available, the estimation of our model using PB data for 2006/7 requires the resolution of several other issues.

Estimation issue 1: 'net spend' or 'own population' spend?

The Department of Health reports two sets of PB spend data: the first is on a 'net spend' basis and the second is on an 'own population' basis. The 'own population' data starts with the 'net spend' figure, adds any expenditure funded from non-NHS sources, and adjusts for expenditure made under PCT lead/host commissioning arrangements. These adjustments are usually very small. For 2005/6 we used the net spend data (because only net spend data was produced in the first year and we were hoping to build a panel) but given the now regular production of own population data this would seem to be the more appropriate data set to use as, for example, it includes all expenditure irrespective of its funding source.

Estimation issue 2: to weight or not to weight?

Ordinary least squares and IV estimation implicitly gives the same weight to each PCT when estimating our expenditure and outcome models. With the reorganisation of PCTs in October 2006, the number of such organisations was reduced from 303 to 152. However, far from making them more similar in terms of size (as measured by their population), this reorganisation actually increased the disparity in size between the largest and the smallest PCTs, with the largest PCT now being 14 times the size of the smallest. Unless we explicitly weight each observation (PCT) by its size, we will be giving the same weight (influence) to PCTs that are much smaller than other PCTs.

Estimation issue 3: which market forces factors?

This study builds on previous work using PB data. Martin *et al.*[59] report the results of the estimation of our model using PB data for 2006/7. One essential step in this estimation is the removal of the impact of unavoidable variations in local costs from the reported measure of the 'unified weighted' population. At the time of the earlier study the authors only had access to a MFF based on HCHS for the new 152 PCTs. Now, however, a more broadly-based MFF is available, that is, one based on a weighted average of MFFs for HCHS, prescribing, and GMS/PMS. Should we use a MFF for HCHS only, or one that incorporates HCHS and prescribing, or one that incorporates HCHS, prescribing and GMS/PMS?

Estimation issue 4: standardised mortality rates or standardised years of life lost rates, and which proxy for the other programme need variable?

Previous studies have reported results using both SMRs and SYLLRs but the sheer number of models being estimated requires that we focus on one measure only. Various proxies for other programme need have been employed in previous studies (see section *Other estimation issues* for further discussion). In this subsection we persevere with this variety but consistency demands that we focus in on a preferred proxy for other programme need.

This study builds on previous work using PB data. Martin *et al.*[59] report the results of the estimation of our model using PB data for 2006/7. With several alternative measures of need and MFF available, we undertook a preliminary empirical analysis of the 2006/7 PB data using the outcome and expenditure models for the big four programmes as reported in Martin *et al.*[59] as our starting point. These models incorporated the AREA-based measure of need and a MFF based on HCHS only.

We first re-estimated the outcome and expenditure models by replacing the AREA-based measure of need with one incorporating the PBRA formula. Then we re-estimated these models again with a measure of need incorporating the CARAN model. The results suggest that (a) for the outcome models, the use of the PBRA measure of need generates a smaller coefficient on expenditure than does the AREA measure of need; and (b) that for the spend models, the use of the PBRA measure of need generates a larger coefficient on PCT budget than does the AREA measure of need. For both the outcome and expenditure models, the use of the CARAN measure of need generates outcome and expenditure elasticities that lie between those generated by the AREA and PBRA measures.

Next, the results reported by Martin *et al.*[59] employ a MFF based on HCHS only to remove unavoidable variations in local costs from the reported measure of the (unified weighted) need for health-care services. This was the only MFF available for the new PCTs at the time of that study. Now, however, a more broadly-based MFF is available (that is, one based on a weighted average of MFFs for HCHS, prescribing, and GMS/PMS).

To examine the consequences of using the CARAN MFF (i.e. a weighted average of the HCHS, prescribing, and GMS/PMS MFFs), this MFF was used to calculate the implied level of need given the unified weighted populations for 2006/7 which are reported alongside the PB spend data by the Department of Health.[aa] We found that the use of an extended set of MFFs can sometimes affect the coefficient on the variable of interest.

Models were also estimated using a weighted average of the CARAN MFFs for HCHS and prescribing only. The latter results were very similar to those using all three of the CARAN MFFs (i.e. a weighted average of the HCHS, prescribing, and GMS/PMS MFFs).

We also tried re-estimating the outcome and expenditure models from Martin *et al.*[59] using the 'own population' expenditure data rather than the 'net spend' data but this adjustment had very little effect on the results. In addition, the impact of 'weighting' each observation by PCT size was usually rather modest.

Because of the sheer number of variations possible, we decided to estimate 13 particular variants of our model and details of these variants are summarised in *Table 50*. These variants were estimated for each of the big four programmes using both the outcome and expenditure equations. The results are presented in *Tables 51–58*.

TABLE 50 Table showing variants of the outcome and expenditure models estimated using 2006/7 spend data

Variant	PCTs weighted?	MFF indicator	Indicator of need	Mortality indicator
1	No weights	HCHS	AREA-based UWP/HCHS MFF	SMR
2	No weights	HCHS	PBRA model applied to patients on list at 1 April 2006	SMR
3	No weights	HCHS	CARAN model used for allocations in 2009/10	SMR
4	No weights	HCHS	AREA-based UWP/HCHS MFF	SYLLR
5	No weights	HCHS	PBRA model applied to patients on list at 1 April 2006	SYLLR
6	No weights	HCHS	CARAN model used for allocations in 2009/10	SYLLR
7	Yes	HCHS	AREA-based UWP/HCHS MFF	SMR
8	No weights	HCHS, prescribing and GMS/PMS	AREA-based UWP/(HCHS, prescribing and GMS/PMS) MFF	SMR
9	Yes	HCHS, prescribing and GMS/PMS	AREA-based UWP/(HCHS, prescribing and GMS/PMS) MFF	SMR
10	No weights	HCHS and prescribing	AREA-based UWP/(HCHS and prescribing) MFF	SMR
11	Yes	HCHS and prescribing	AREA-based UWP/(HCHS and prescribing) MFF	SMR
12	No weights	HCHS, prescribing and GMS	CARAN model used for allocations in 2009/10	SMR
13	Yes	HCHS, prescribing and GMS	CARAN model used for allocations in 2009/10	SMR

UWP, unified weighted population.

TABLE 51 Table showing cancer spend models with various indicators of MFF and need

	PBC 2 cancer, 2006/7, spend model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
PCT budget per head	0.353	0.681***	0.572**	0.388	0.752***	0.618**	0.326	0.250	0.245	0.246	0.241	0.552**	0.544*
	[0.273]	[0.235]	[0.247]	[0.272]	[0.238]	[0.247]	[0.362]	[0.284]	[0.357]	[0.284]	[0.357]	[0.239]	[0.308]
NeedAREA1	1.513***			1.557***			1.351***						
	[0.288]			[0.284]			[0.367]						
Other programme need 1	−0.654***	−0.771***	−0.733***				−0.604***	−0.749***	−0.661***	−0.749***	−0.661***	−0.680***	−0.616***
	[0.124]	[0.125]	[0.124]				[0.131]	[0.152]	[0.154]	[0.151]	[0.154]	[0.126]	[0.139]
NeedPBRA		1.320***			1.352***								
		[0.261]			[0.265]								
NeedCARAN			1.431***			1.477***						1.347***	1.160***
			[0.287]			[0.289]						[0.246]	[0.294]
Other programme need 2				−0.649***	−0.773***	−0.728***							
				[0.119]	[0.124]	[0.119]							
NeedAREA2								1.778***	1.554***				
								[0.329]	[0.389]				
NeedAREA3										1.765***	1.545***		
										[0.328]	[0.388]		
Constant	0.271	0.707	0.569	0.356	0.835	0.665	0.067	5.901***	5.559**	5.932***	5.582**	3.430**	3.220
	[0.544]	[0.551]	[0.554]	[0.542]	[0.567]	[0.554]	[0.572]	[2.062]	[2.550]	[2.063]	[2.550]	[1.645]	[2.087]
Observations	152	152	152	152	152	152	152	152	152	152	152	152	152

Variable	PBC 2 cancer, 2006/7, spend model												
	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Endogeneity test statistic	13.112	18.683	18.420	13.313	18.736	18.716	11.940	13.098	11.708	13.017	11.504	16.985	13.460
Endogeneity *p*-value	0.000293	1.54e-05	1.77e-05	0.000264	1.50e-05	1.52e-05	0.000549	0.000296	0.000622	0.000309	0.000695	3.77e-05	0.000244
Hansen–Sargan test statistic	0.870	1.139	0.560	0.504	0.748	0.281	1.089	1.730	1.875	1.711	1.857	0.381	0.321
Hansen–Sargan *p*-value	0.351	0.286	0.454	0.478	0.387	0.596	0.297	0.188	0.171	0.191	0.173	0.537	0.571
Shea's partial R^2	0.607	0.526	0.586	0.570	0.482	0.548	0.612	0.511	0.537	0.510	0.536	0.572	0.583
Kleibergen–Paap LM test statistic	40.55	38.73	40.45	40.49	38.17	41.14	38.91	38.41	37.13	38.38	37.11	43.82	41.36
Kleibergen–Paap *p*-value	1.57e-09	3.88e-09	1.64e-09	1.61e-09	5.14e-09	1.16e-09	3.55e-09	4.56e-09	8.66e-09	4.63e-09	8.75e-09	3.06e-10	1.05e-09
Kleibergen–Paap *F*-statistic	73.17	63.72	68.50	67.14	51.14	60.78	72.14	57.74	61.44	58.09	61.58	68.29	66.96
Pesaran–Taylor reset statistic	0.233	0.299	0.0271	0.198	0.211	0.00518	0.000324	0.00529	0.0391	0.0345	0.00971	9.41e-07	0.0158
Pesaran–Taylor *p*-value	0.629	0.585	0.869	0.656	0.646	0.943	0.986	0.942	0.843	0.853	0.922	0.999	0.900

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
iAREA need 1 = AREA unified weighted population/HCHS MFF.
iAREA need 2 = AREA unified weighted population/HCHS, prescribing and GMS/PMS MFFs.
iAREA need 3 = AREA unified weighted population/HCHS and prescribing MFFs.
Other programme need 1 = circulatory disease SMR.
Other programme need 2 = circulatory disease SYLLR.

TABLE 52 Table showing circulatory disease spend models with various indicators of MFF and need

	PBC 10 circulation, 2006/7, spend model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Other programme need 1	−0.766**	−0.736**	−0.811**				−0.939***	−0.776**	−0.927***	−0.781**	−0.935***	−0.831**	−1.112***
	[0.298]	[0.299]	[0.370]				[0.305]	[0.315]	[0.324]	[0.316]	[0.326]	[0.367]	[0.392]
PCT budget per head	0.861***	1.162***	1.035***	0.836***	1.191***	0.998***	0.719***	0.832***	0.661**	0.829***	0.657**	0.983***	0.914***
	[0.240]	[0.218]	[0.219]	[0.229]	[0.220]	[0.210]	[0.259]	[0.242]	[0.264]	[0.242]	[0.264]	[0.213]	[0.231]
NeedAREA1	0.624*			0.732*			0.967**						
	[0.355]			[0.389]			[0.378]						
White ethnic group	0.215***	0.187**	0.207**	0.232***	0.199**	0.225**	0.278***	0.219**	0.284***	0.219**	0.284***	0.209**	0.286***
	[0.079]	[0.080]	[0.086]	[0.083]	[0.083]	[0.095]	[0.084]	[0.085]	[0.091]	[0.085]	[0.091]	[0.086]	[0.098]
Provision of unpaid care	0.457**	0.554***	0.488**	0.437**	0.549***	0.466*	0.239	0.527***	0.336	0.528***	0.335	0.477**	0.200
	[0.205]	[0.186]	[0.227]	[0.212]	[0.183]	[0.247]	[0.227]	[0.190]	[0.210]	[0.190]	[0.211]	[0.227]	[0.268]
NeedPBRA		0.250			0.295								
		[0.275]			[0.280]								
NeedCARAN			0.480			0.610						0.546	0.925**
			[0.401]			[0.479]						[0.369]	[0.399]

Variable	PBC 10 circulation, 2006/7, spend model												
	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Other programme need 2				–0.904**	–0.871**	–0.956*							
				[0.365]	[0.347]	[0.491]							
NeedAREA2								0.655*	1.020**				
								[0.383]	[0.424]				
NeedAREA3										0.652*	1.018**		
										[0.381]	[0.422]		
Constant	2.380**	2.377*	2.621*	3.246**	3.244**	3.533*	2.744**	3.763*	5.275**	3.803*	5.337**	2.827	4.028**
	[1.212]	[1.251]	[1.469]	[1.572]	[1.553]	[2.088]	[1.222]	[2.133]	[2.306]	[2.143]	[2.319]	[1.863]	[1.995]
Observations	152	152	152	152	152	152	152	152	152	152	152	152	152
Endogeneity test statistic	8.506	10.727	8.136	6.475	8.793	5.743	9.019	8.939	8.654	9.036	8.745	8.315	9.729
Endogeneity *p*-value	0.00354	0.00106	0.00434	0.0109	0.00302	0.0166	0.00267	0.00279	0.00326	0.00265	0.00310	0.00393	0.00181
Hansen–Sargan test statistic	2.454	0.640	1.841	2.364	0.423	2.166	2.993	1.770	2.225	1.792	2.237	1.777	2.030
Hansen–Sargan *p*-value	0.117	0.424	0.175	0.124	0.515	0.141	0.0836	0.183	0.136	0.181	0.135	0.183	0.154

continued

TABLE 52 Table showing circulatory disease spend models with various indicators of MFF and need (*continued*)

	PBC 10 circulation, 2006/7, spend model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Shea's partial R^2	0.235	0.205	0.184	0.207	0.184	0.148	0.238	0.225	0.230	0.224	0.228	0.183	0.183
Kleibergen–Paap LM test statistic	22.99	24.15	20.59	21.32	25.01	17.46	26.79	23.47	27.59	23.63	27.59	20.91	24.11
Kleibergen–Paap *p*-value	1.02e-05	5.70e-06	3.39e-05	2.35e-05	3.70e-06	0.000161	1.52e-06	8.02e-06	1.02e-06	7.41e-06	1.02e-06	2.88e-05	5.80e-06
Kleibergen–Paap *F*-statistic	23.14	22.53	18.64	17.28	20.44	12.62	22.37	21.47	22.07	21.27	21.63	19.10	18.93
Pesaran–Taylor reset statistic	0.00329	0.156	0.102	0.0384	0.333	0.288	0.0270	0.123	0.152	0.189	0.235	0.0165	0.190
Pesaran–Taylor *p*-value	0.954	0.693	0.750	0.845	0.564	0.592	0.869	0.726	0.696	0.664	0.628	0.898	0.663

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
iAREA need 1 = AREA unified weighted population/HCHS MFF.
iAREA need 2 = AREA unified weighted population/HCHS, prescribing and GMS/PMS MFFs.
iAREA need 3 = AREA unified weighted population/HCHS and prescribing MFFs.
Other programme need 1 = cancer SMR.
Other programme need 2 = cancer SYLLR.

TABLE 53 Table showing respiratory problems spend models with various indicators of MFF and need

	PBC 11 respiratory, 2006/7, spend model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
PCT budget per head	0.781**	0.992***	0.957***	1.045***	1.315***	1.204***	0.808**	0.592**	0.591*	0.588**	0.585*	0.865***	0.958***
	[0.318]	[0.330]	[0.363]	[0.370]	[0.409]	[0.432]	[0.334]	[0.282]	[0.310]	[0.283]	[0.310]	[0.287]	[0.329]
NeedAREA1	1.714***			1.741***			1.813***						
	[0.597]			[0.497]			[0.563]						
Lone pensioner households	−0.497	−0.243	−0.483	−0.419*	−0.240	−0.380	−0.595*	−0.078	−0.304	−0.089	−0.320	−0.447	−0.556
	[0.346]	[0.243]	[0.356]	[0.252]	[0.210]	[0.271]	[0.346]	[0.285]	[0.378]	[0.286]	[0.380]	[0.337]	[0.344]
Other programme need 1	−0.803**	−0.602**	−0.890**				−0.866**	−0.391	−0.664	−0.407	−0.687	−0.834*	−0.931**
	[0.397]	[0.294]	[0.439]				[0.392]	[0.364]	[0.478]	[0.364]	[0.481]	[0.428]	[0.437]
NeedPBRA		1.176***			1.226***								
		[0.391]			[0.366]								
NeedCARAN			1.686***			1.720***						1.680***	1.782***
			[0.627]			[0.536]						[0.609]	[0.561]
Other programme need 2				−1.109**	−0.955**	−1.197**							
				[0.455]	[0.406]	[0.552]							

continued

TABLE 53 Table showing respiratory problems spend models with various indicators of MFF and need (*continued*)

	PBC 11 respiratory, 2006/7, spend model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
NeedAREA2								1.312**	1.770**				
								[0.667]	[0.803]				
NeedAREA3										1.325**	1.788**		
										[0.661]	[0.800]		
Constant	–0.143	–0.649	0.258	2.954	2.293	3.531	–0.046	1.605	2.457	1.686	2.578	1.022	0.595
	[1.250]	[0.961]	[1.415]	[2.335]	[2.094]	[2.856]	[1.220]	[2.372]	[2.547]	[2.389]	[2.574]	[1.980]	[2.082]
Observations	152	152	152	152	152	152	152	152	152	152	152	152	152
Endogeneity test statistic	7.821	8.431	9.089	9.157	10.215	9.242	6.984	4.679	4.326	4.853	4.475	9.016	6.863
Endogeneity *p*-value	0.00516	0.00369	0.00257	0.00248	0.00139	0.00236	0.00822	0.0305	0.0375	0.0276	0.0344	0.00268	0.00880
Hansen–Sargan test statistic	1.655	3.108	0.983	0.214	1.502	0.0135	0.615	4.704	2.922	4.621	2.855	0.866	0.156
Hansen-Sargan *p*-value	0.198	0.0779	0.321	0.644	0.220	0.908	0.433	0.0301	0.0874	0.0316	0.0911	0.352	0.693
Shea's partial R^2	0.164	0.211	0.149	0.183	0.203	0.172	0.167	0.161	0.131	0.161	0.131	0.142	0.146

Variable	PBC 11 respiratory, 2006/7, spend model												
	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Kleibergen–Paap LM test statistic	18.58	21.08	18.17	22.04	17.51	18.27	18.78	20.00	13.94	20.14	13.90	17.12	16.62
Kleibergen–Paap *p*-value	9.22e-05	2.64e-05	0.000113	1.64e-05	0.000158	0.000108	8.34e-05	4.55e-05	0.000940	4.23e-05	0.000960	0.000192	0.000246
Kleibergen–Paap *F*-statistic	8.163	14.31	7.772	8.729	8.513	6.885	8.383	13.56	7.241	13.77	7.297	7.776	7.220
Pesaran–Taylor reset statistic	0.238	0.0135	0.141	0.0704	0.0139	0.0164	1.083	2.231	2.206	2.311	2.283	3.699	4.984
Pesaran–Taylor *p*-value	0.625	0.907	0.707	0.791	0.906	0.898	0.298	0.135	0.138	0.128	0.131	0.0545	0.0256

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
iAREA need 1 = AREA unified weighted population/HCHS MFF.
iAREA need 2 = AREA unified weighted population/HCHS, prescribing and GMS/PMS MFFs.
iAREA need 3 = AREA unified weighted population/HCHS and prescribing MFFs.
Other programme need 1 = SMR for all causes of death amenable to health care (see Martin *et al.*[63]).
Other programme need 2 = SYLLR for all causes of death.

TABLE 54 Table showing gastrointestinal problems spend models with various indicators of MFF and need

	PBC 13 gastrointestinal, 2006/7, spend model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
PCT budget per head	0.538	0.876**	0.862**	1.058**	1.461***	1.396***	0.627*	0.240	0.271	0.237	0.265	0.509*	0.692**
	[0.355]	[0.371]	[0.414]	[0.446]	[0.513]	[0.533]	[0.371]	[0.301]	[0.334]	[0.301]	[0.334]	[0.305]	[0.340]
NeedAREA1	2.627***			2.840***			2.775***						
	[0.851]			[0.758]			[0.755]						
Lone pensioner households	−0.838*	−0.269	−0.740	−0.793**	−0.362	−0.736*	−1.080**	0.122	−0.262	0.121	−0.270	−0.612	−0.901**
	[0.492]	[0.347]	[0.520]	[0.385]	[0.314]	[0.422]	[0.460]	[0.290]	[0.375]	[0.287]	[0.374]	[0.453]	[0.445]
Other programme need 1	−1.386**	−0.820**	−1.416**				−1.572***	−0.279	−0.751	−0.281	−0.763	−1.216**	−1.510***
	[0.566]	[0.402]	[0.634]				[0.520]	[0.366]	[0.476]	[0.363]	[0.475]	[0.562]	[0.552]
NeedPBRA		1.422***			1.627***								
		[0.488]			[0.478]								
NeedCARAN			2.369***			2.740***						2.375***	2.619***
			[0.889]			[0.839]						[0.836]	[0.748]

Variable	PBC 13 gastrointestinal, 2006/7, spend model												
	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Other programme need 2				−2.093***	−1.524***	−2.250***							
				[0.663]	[0.588]	[0.817]							
NeedAREA2								1.267*	1.916**				
								[0.662]	[0.794]				
NeedAREA3										1.264*	1.920**		
										[0.650]	[0.784]		
Constant	2.133	0.486	2.386	8.379**	5.626*	9.374**	2.512	4.107	5.367*	4.129	5.450*	5.180**	4.691**
	[1.763]	[1.237]	[1.998]	[3.338]	[2.958]	[4.164]	[1.605]	[2.520]	[2.774]	[2.524]	[2.787]	[2.437]	[2.310]
Observations	152	152	152	152	152	152	152	152	152	152	152	152	152
Endogeneity test statistic	3.530	1.329	4.118	11.390	5.366	9.900	7.202	0.041	1.085	0.052	1.144	4.849	8.194
Endogeneity *p*-value	0.0603	0.249	0.0424	0.000738	0.0205	0.00165	0.00728	0.839	0.298	0.820	0.285	0.0277	0.00420
Hansen–Sargan test statistic	7.192	9.154	4.655	2.282	6.867	1.169	5.058	12.98	11.45	12.91	11.31	4.276	2.414
Hansen–Sargan *p*-value	0.00732	0.00248	0.0310	0.131	0.00878	0.280	0.0245	0.000316	0.000715	0.000327	0.000771	0.0387	0.120
Shea's partial R^2	0.164	0.211	0.149	0.183	0.203	0.172	0.167	0.161	0.131	0.161	0.131	0.142	0.146

continued

TABLE 54 Table showing gastrointestinal problems spend models with various indicators of MFF and need (*continued*)

	PBC 13 gastrointestinal, 2006/7, spend model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Kleibergen–Paap LM test statistic	18.58	21.08	18.17	22.04	17.51	18.27	18.78	20.00	13.94	20.14	13.90	17.12	16.62
Kleibergen–Paap *p*-value	9.22e-05	2.64e-05	0.000113	1.64e-05	0.000158	0.000108	8.34e-05	4.55e-05	0.000940	4.23e-05	0.000960	0.000192	0.000246
Kleibergen–Paap *F*-statistic	8.163	14.31	7.772	8.729	8.513	6.885	8.383	13.56	7.241	13.77	7.297	7.776	7.220
Pesaran–Taylor reset statistic	0.00544	0.107	0.00251	0.0613	0.0576	0.000667	0.167	1.735	2.598	1.752	2.633	2.450	3.579
Pesaran–Taylor *p*-value	0.941	0.743	0.960	0.804	0.810	0.979	0.683	0.188	0.107	0.186	0.105	0.118	0.0585

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
iAREA need 1 = AREA unified weighted population/HCHS MFF.
iAREA need 2 = AREA unified weighted population/HCHS, prescribing and GMS/PMS MFFs.
iAREA need 3 = AREA unified weighted population/HCHS and prescribing MFFs.
Other programme need 1 = SMR for all causes of death amenable to health care (see Martin *et al.*[63]).
Other programme need 2 = SYLLR for all causes of death.

TABLE 55 Table showing cancer outcome models with various indicators of MFF and need

	PBC 2 cancer, 2006/7, outcome model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
NeedAREA1	1.142***			1.048***			1.121***						
	[0.161]			[0.143]			[0.169]						
Cancer spend per head	−0.426***	−0.287***	−0.351***	−0.356***	−0.223***	−0.291***	−0.487***	−0.284***	−0.367***	−0.284***	−0.366***	−0.421***	−0.494***
	[0.125]	[0.080]	[0.098]	[0.110]	[0.068]	[0.082]	[0.148]	[0.109]	[0.133]	[0.109]	[0.133]	[0.126]	[0.156]
NeedPBRA		0.972***			0.881***								
		[0.104]			[0.090]								
NeedCARAN			1.087***			1.005***						1.126***	1.112***
			[0.130]			[0.110]						[0.153]	[0.167]
NeedAREA2								1.048***	1.070***				
								[0.128]	[0.143]				
NeedAREA3										1.035***	1.058***		
										[0.128]	[0.142]		
Constant	3.689***	4.049***	3.884***	4.139***	4.482***	4.309***	3.536***	6.012***	6.375***	6.009***	6.373***	6.614***	6.938***
	[0.318]	[0.202]	[0.249]	[0.278]	[0.172]	[0.207]	[0.372]	[0.476]	[0.583]	[0.476]	[0.583]	[0.552]	[0.684]
Observations	152	152	152	152	152	152	152	152	152	152	152	152	152
Endogeneity test statistic	18.518	16.063	19.086	15.982	12.454	17.096	18.965	11.026	13.552	10.985	13.490	19.697	19.500
Endogeneity *p*-value	1.68e-05	6.13e-05	1.25e-05	6.40e-05	0.000417	3.55e-05	1.33e-05	0.000898	0.000232	0.000918	0.000240	9.07e-06	1.01e-05

continued

TABLE 55 Table showing cancer outcome models with various indicators of MFF and need (*continued*)

	PBC 2 cancer, 2006/7, outcome model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Hansen–Sargan test statistic	0.248	0.239	0.0431	0.163	0.161	0.00820	0.192	0.860	0.690	0.857	0.686	0.000632	0.0933
Hansen–Sargan *p*-value	0.619	0.625	0.835	0.686	0.688	0.928	0.661	0.354	0.406	0.355	0.407	0.980	0.760
Shea's partial R^2	0.200	0.246	0.226	0.200	0.246	0.226	0.176	0.202	0.167	0.202	0.166	0.169	0.142
Kleibergen–Paap LM test statistic	18.49	23.43	21.27	18.49	23.43	21.27	16.89	19.40	17.25	19.39	17.20	18.35	15.71
Kleibergen–Paap *p*-value	9.66e-05	8.17e-06	2.41e-05	9.66e-05	8.17e-06	2.41e-05	0.000215	6.12e-05	0.000179	6.17e-05	0.000184	0.000104	0.000389
Kleibergen–Paap *F*-statistic	19.15	28.08	24.39	19.15	28.08	24.39	15.16	19.90	14.69	19.81	14.58	16.81	12.05
Pesaran–Taylor reset statistic	2.789	5.422	3.218	3.506	5.986	3.796	3.838	4.129	5.271	4.234	5.259	4.399	5.890
Pesaran–Taylor *p*-value	0.0949	0.0199	0.0728	0.0611	0.0144	0.0514	0.0501	0.0422	0.0217	0.0396	0.0218	0.0360	0.0152

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
iAREA need 1 = AREA unified weighted population/HCHS MFF.
iAREA need 2 = AREA unified weighted population/HCHS, prescribing and GMS/PMS MFFs.
iAREA need 3 = AREA unified weighted population/HCHS and prescribing MFFs.

TABLE 56 Table showing circulatory disease outcome models with various indicators of MFF and need

	PBC 10 circulation, 2006/7, outcome model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
NeedAREA1	2.442***			2.657***			2.554***						
	[0.239]			[0.256]			[0.251]						
Circulation spend per head	−1.166***	−0.945***	−1.080***	−1.245***	−0.983***	−1.138***	−1.258***	−0.968***	−1.077***	−0.966***	−1.075***	−1.285***	−1.379***
	[0.203]	[0.180]	[0.195]	[0.215]	[0.190]	[0.205]	[0.207]	[0.191]	[0.194]	[0.191]	[0.194]	[0.243]	[0.238]
NeedPBRA		2.104***			2.262***								
		[0.208]			[0.220]								
NeedCARAN			2.394***			2.587***						2.508***	2.624***
			[0.242]			[0.257]						[0.278]	[0.282]
NeedAREA2								2.303***	2.452***				
								[0.218]	[0.233]				
NeedAREA3										2.281***	2.426***		
										[0.217]	[0.231]		
Constant	1.971***	2.456***	2.165***	1.983***	2.555***	2.222***	1.771***	9.078***	9.596***	9.073***	9.584***	10.605***	11.050***
	[0.429]	[0.379]	[0.411]	[0.454]	[0.400]	[0.432]	[0.438]	[0.916]	[0.931]	[0.914]	[0.928]	[1.168]	[1.145]
Observations	152	152	152	152	152	152	152	152	152	152	152	152	152
Endogeneity test statistic	32.774	30.750	39.253	38.776	28.130	42.881	28.691	28.410	28.030	28.471	27.939	40.272	38.934
Endogeneity *p*-value	1.04e-08	2.94e-08	3.72e-10	4.75e-10	1.13e-07	5.82e-11	8.49e-08	9.82e-08	1.19e-07	9.51e-08	1.25e-07	2.21e-10	4.38e-10

continued

TABLE 56 Table showing circulatory disease outcome models with various indicators of MFF and need (*continued*)

	PBC 10 circulation, 2006/7, outcome model												
Variable	(1) Uses SMR, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, weighted, second stage, CARAN need, CARAN 3 MFFs
Hansen–Sargan test statistic	7.315	11.76	3.706	5.337	12.53	3.288	5.937	10.43	7.965	10.24	7.888	2.449	1.678
Hansen–Sargan *p*-value	0.0625	0.00827	0.295	0.149	0.00576	0.349	0.115	0.0153	0.0467	0.0166	0.0484	0.484	0.642
Shea's partial R^2	0.368	0.383	0.376	0.368	0.383	0.376	0.349	0.370	0.346	0.371	0.347	0.305	0.291
Kleibergen–Paap LM test statistic	29.32	26.93	31.11	29.32	26.93	31.11	32.68	31.06	34.79	31.25	34.98	28.69	31.43
Kleibergen–Paap *p*-value	6.73e-06	2.05e-05	2.90e-06	6.73e-06	2.05e-05	2.90e-06	1.39e-06	2.97e-06	5.14e-07	2.72e-06	4.70e-07	9.03e-06	2.50e-06
Kleibergen–Paap *F*-statistic	20.24	19.21	20.32	20.24	19.21	20.32	19.89	20.09	19.66	20.15	19.70	15.50	16.33
Pesaran–Taylor reset statistic	0.0847	0.0884	2.19e-07	0.257	0.0261	0.0107	0.0185	0.0138	0.00282	0.0143	0.00315	2.369	0.196
Pesaran–Taylor *p*-value	0.771	0.766	1.000	0.612	0.872	0.918	0.892	0.906	0.958	0.905	0.955	0.124	0.658

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
iAREA need 1 = AREA unified weighted population/HCHS MFF.
iAREA need 2 = AREA unified weighted population/HCHS, prescribing and GMS/PMS MFFs.
iAREA need 3 = AREA unified weighted population/HCHS and prescribing MFFs.

TABLE 57 Table showing respiratory disease outcome models with various indicators of MFF and need

	PBC 11 respiratory, 2006/7, outcome model												
Variable	(1) Uses SMR, instrument spend, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, instrument spend, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, instrument spend, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, instrument spend, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, instrument spend, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, instrument spend, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, instrument spend, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, instrument spend, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, instrument spend, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, instrument spend, no weighting second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, instrument spend, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, instrument spend, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, instrument spend, weighted, second stage, CARAN need, CARAN 3 MFFs
NeedAREA1	8.008***			9.158***			8.647***						
	[2.969]			[3.298]			[3.317]						
Respiratory spend per head	−4.845**	−3.364***	−4.149**	−5.568**	−3.894***	−4.808**	−5.182**	−3.535**	−3.773**	−3.536**	−3.764**	−6.738*	−6.640*
	[2.147]	[1.225]	[1.734]	[2.388]	[1.359]	[1.945]	[2.352]	[1.412]	[1.503]	[1.400]	[1.479]	[3.799]	[3.464]
NeedPBRA		5.941***			6.789***								
		[1.706]			[1.887]								
NeedCARAN			7.238***			8.306***						10.184**	10.352**
			[2.492]			[2.788]						[5.006]	[4.635]
NeedAREA2								6.501***	7.025***				
								[1.985]	[2.176]				
NeedAREA3										6.460***	6.965***		
										[1.959]	[2.130]		
Constant	−10.277*	−6.163*	−8.328*	−12.218*	−7.567**	−10.087*	−11.234*	17.749***	18.712***	17.755***	18.675***	31.101**	30.667**
	[5.898]	[3.355]	[4.749]	[6.563]	[3.723]	[5.328]	[6.465]	[5.877]	[6.252]	[5.824]	[6.151]	[15.828]	[14.436]
Observations	152	152	152	152	152	152	152	152	152	152	152	152	152
Endogeneity test statistic	51.569	49.552	54.608	55.731	52.069	58.974	48.137	42.431	44.464	42.671	44.683	57.889	53.094

continued

TABLE 57 Table showing respiratory disease outcome models with various indicators of MFF and need (*continued*)

	PBC 11 respiratory, 2006/7, outcome model												
Variable	(1) Uses SMR, instrument spend, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, instrument spend, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, instrument spend, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, instrument spend, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, instrument spend, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, instrument spend, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, instrument spend, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, instrument spend, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, instrument spend, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, instrument spend, no weighting second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, instrument spend, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, instrument spend, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, instrument spend, weighted, second stage, CARAN need, CARAN 3 MFFs
Endogeneity *p*-value	0	0	0	0	0	0	0	7.32e-11	0	6.48e-11	0	0	0
Hansen–Sargan test statistic	0.302	1.253	0.123	0.305	1.828	0.211	0.179	0.785	0.354	0.700	0.303	0.00383	0.0915
Hansen–Sargan *p*-value	0.582	0.263	0.726	0.581	0.176	0.646	0.673	0.376	0.552	0.403	0.582	0.951	0.762
Shea's partial R^2	0.0491	0.0791	0.0593	0.0491	0.0791	0.0593	0.0462	0.0654	0.0624	0.0661	0.0633	0.0235	0.0246
Kleibergen–Paap LM test statistic	5.660	8.303	7.499	5.660	8.303	7.499	5.437	7.311	6.973	7.461	7.117	3.866	3.772
Kleibergen–Paap *p*-value	0.0590	0.0157	0.0235	0.0590	0.0157	0.0235	0.0660	0.0258	0.0306	0.0240	0.0285	0.145	0.152
Kleibergen–Paap *F*-statistic	3.344	5.857	4.507	3.344	5.857	4.507	2.959	4.328	3.804	4.402	3.875	2.030	1.859
Pesaran–Taylor reset statistic	0.791	4.049	0.000560	1.490	5.225	0.00355	0.327	0.0202	0.00861	0.0218	0.0116	3.788	1.716
Pesaran–Taylor *p*-value	0.374	0.0442	0.981	0.222	0.0223	0.952	0.568	0.887	0.926	0.883	0.914	0.0516	0.190

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
iAREA need 1 = AREA unified weighted population/HCHS MFF.
iAREA need 2 = AREA unified weighted population/HCHS, prescribing and GMS/PMS MFFs.
iAREA need 3 = AREA unified weighted population/HCHS and prescribing MFFs.

TABLE 58 Table showing gastrointestinal disease outcome models with various indicators of MFF and need

	PBC 13 gastrointestinal, 2006/7, outcome model												
Variable	(1) Uses SMR, instrument spend, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, instrument spend, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, instrument spend, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, instrument spend, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, instrument spend, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, instrument spend, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, instrument spend, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, instrument spend, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, instrument spend, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, instrument spend, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, instrument spend, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, instrument spend, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, instrument spend, weighted, second stage, CARAN need, CARAN 3 MFFs
NeedAREA1	3.853***			3.966***			3.779***						
	[0.551]			[0.558]			[0.499]						
Gastrointestinal spend per head	−1.755***	−1.420***	−1.641***	−1.544***	−1.180***	−1.404***	−1.750***	−1.275***	−1.317***	−1.275***	−1.315***	−2.056***	−2.192***
	[0.397]	[0.353]	[0.427]	[0.399]	[0.358]	[0.429]	[0.385]	[0.335]	[0.326]	[0.335]	[0.325]	[0.589]	[0.574]
NeedPBRA		3.342***			3.413***								
		[0.486]			[0.498]								
NeedCARAN			3.794***			3.887***						4.140***	4.250***
			[0.612]			[0.621]						[0.768]	[0.710]
NeedAREA2								3.426***	3.479***				
								[0.466]	[0.419]				
NeedAREA3										3.393***	3.443***		
										[0.462]	[0.415]		
Constant	−2.155**	−1.251	−1.838	−0.954	0.028	−0.566	−2.166**	7.919***	8.073***	7.916***	8.064***	11.273***	11.835***
	[1.047]	[0.928]	[1.121]	[1.054]	[0.943]	[1.127]	[1.016]	[1.431]	[1.391]	[1.430]	[1.387]	[2.524]	[2.460]
Observations	152	152	152	152	152	152	152	152	152	152	152	152	152
Endogeneity test statistic	23.347	18.985	25.405	17.048	11.389	17.857	16.834	16.638	11.980	16.689	11.942	25.632	22.341

continued

TABLE 58 Table showing gastrointestinal disease outcome models with various indicators of MFF and need (*continued*)

Variable	PBC 13 gastrointestinal, 2006/7, outcome model												
	(1) Uses SMR, instrument spend, no weighting, second stage, iAREA need 1, HCHS MFF	(2) Uses SMR, instrument spend, no weighting, second stage, PBRA need, HCHS MFF	(3) Uses SMR, instrument spend, no weighting, second stage, CARAN need, HCHS MFF	(4) Uses SYLLR, instrument spend, no weighting, second stage, iAREA need 1, HCHS MFF	(5) Uses SYLLR, instrument spend, no weighting, second stage, PBRA need, HCHS MFF	(6) Uses SYLLR, instrument spend, no weighting, second stage, CARAN need, HCHS MFF	(7) Uses SMR, instrument spend, weighted, second stage, iAREA need 1, HCHS MFF	(8) Uses SMR, instrument spend, no weighting, second stage, iAREA need 2, CARAN 3 MFFs	(9) Uses SMR, instrument spend, weighted, second stage, iAREA need 2, CARAN 3 MFFs	(10) Uses SMR, instrument spend, no weighting, second stage, iAREA need 3, CARAN 2 MFFs	(11) Uses SMR, instrument spend, weighted, second stage, iAREA need 3, CARAN 2 MFFs	(12) Uses SMR, instrument spend, no weighting, second stage, CARAN need, CARAN 3 MFFs	(13) Uses SMR, instrument spend, weighted, second stage, CARAN need, CARAN 3 MFFs
Endogeneity *p*-value	1.35e-06	1.32e-05	4.65e-07	3.65e-05	0.000739	2.38e-05	4.08e-05	4.52e-05	0.000538	4.40e-05	0.000549	4.13e-07	2.28e-06
Hansen–Sargan test statistic	3.067	4.604	1.555	4.936	7.575	2.637	7.476	5.029	8.762	4.907	8.714	1.284	3.554
Hansen–Sargan *p*-value	0.216	0.100	0.459	0.0847	0.0227	0.268	0.0238	0.0809	0.0125	0.0860	0.0128	0.526	0.169
Shea's partial R^2	0.193	0.231	0.200	0.193	0.231	0.200	0.191	0.208	0.198	0.208	0.198	0.139	0.135
Kleibergen–Paap LM test statistic	16.47	17.51	16.32	16.47	17.51	16.32	17.68	17.09	18.26	17.14	18.34	13.39	13.98
Kleibergen–Paap *p*-value	0.000910	0.000556	0.000974	0.000910	0.000556	0.000974	0.000511	0.000679	0.000389	0.000661	0.000375	0.00386	0.00293
Kleibergen–Paap *F*-statistic	12.12	13.24	10.79	12.12	13.24	10.79	11.96	13.23	12.98	13.24	13.00	7.550	7.248
Pesaran–Taylor reset statistic	0.233	0.0427	0.0897	1.246	1.121	0.258	0.170	0.0935	0.443	0.0893	0.411	0.00841	0.117
Pesaran–Taylor *p*-value	0.629	0.836	0.765	0.264	0.290	0.611	0.680	0.760	0.506	0.765	0.521	0.927	0.732

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
iAREA need 1 = AREA unified weighted population/HCHS MFF.
iAREA need 2 = AREA unified weighted population/HCHS, prescribing and GMS/PMS MFFs.
iAREA need 3 = AREA unified weighted population/HCHS and prescribing MFFs.

The assimilation of the impact of alternative measures of need, weights and MFFs proved overwhelming. Instead, we approached the selection of the appropriate need ~ weighting ~ MFF combination from an a priori perspective. The AREA-based need formula has been replaced by the CARAN formula for the purposes of resource allocation and therefore it must be believed to be a better indicator of relative health-care need. The PBRA approach is relatively new and has not been implemented yet. We therefore decided to use the CARAN-based measure as our indicator of the level of need.

With some PCTs several times larger than others, it is difficult to justify giving them all the same weighting. It was therefore decided to weight all of our models by PCT size (where size is measured by the PCT's population).

We also decided to use the 'own population' expenditure data on the grounds that all NHS expenditure, irrespective of its funding source, should be included in the analysis (although there is the issue about how this income is split between PBCs).

Finally, it was decided to focus on the use of the SYLLR as the outcome indicator, and to proxy 'other programme need' in the expenditure equation using the all-cause SYLLR minus the own programme SYLLR.

Model estimation using 2006/7 expenditure data and mortality data for 2004/5/6: CARAN need and three market forces factors

Initially, acceptable models were obtained by using the CARAN measure of need and adjusting expenditure for local input prices using a weighted average of the MFFs for all three services (HCHS, prescribing and GMS/PMS). The outcome and expenditure results for the big four programmes are shown in *Table 59* with the relevant outcome and expenditure elasticities highlighted.

TABLE 59 Table showing outcome and expenditure models for the big four programmes using spend data (incorporating three MFFs) for 2006/7

	PBC 2 cancer, 2006/7		PBC 10 circulation, 2006/7		PBC 11 respiratory, 2006/7		PBC 13 gastrointestinal, 2006/7	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Regressors	Outcome model	Spend model	Outcome model	Spend model	Outcome model	Spend model	Outcome model	Spend model
All-cause SYLLR excluding cancer		−0.952***						
		[0.179]						
Budget per head (HPG MFF)		0.542**		0.694**		0.712***		0.650**
		[0.242]		[0.292]		[0.252]		[0.289]
Need CARAN	0.958***	1.765***	2.830***	2.185***	1.764	1.371***	4.609***	2.696***
	[0.129]	[0.286]	[0.252]	[0.355]	[1.192]	[0.297]	[0.700]	[0.679]
Own programme spend per head	−0.351***		−1.441***		−2.830***		−2.125***	
	[0.117]		[0.219]		[0.767]		[0.563]	
All-cause SYLLR excluding circulatory problems				−1.782***				
				[0.336]				
Permanently sick					1.371***			
					[0.405]			

continued

TABLE 59 Table showing outcome and expenditure models for the big four programmes using spend data (incorporating three MFFs) for 2006/7 (*continued*)

	PBC 2 cancer, 2006/7		PBC 10 circulation, 2006/7		PBC 11 respiratory, 2006/7		PBC 13 gastrointestinal, 2006/7	
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All-cause SYLLR excluding respiratory problems						−0.670**		
						[0.288]		
All-cause SYLLR excluding gastrointestinal problems								−1.856***
								[0.612]
Lone pensioner households								−0.593**
								[0.297]
Constant	6.588***	5.937***	11.538***	10.299***	18.965***	3.117	12.208***	9.752***
	[0.515]	[1.775]	[1.050]	[2.384]	[3.853]	[1.976]	[2.416]	[3.053]
Observations	152	152	152	152	152	152	152	152
Endogeneity test statistic	14.496	20.274	43.352	25.784	27.923	7.922	21.862	13.531
Endogeneity *p*-value	0.000140	6.71e-06	0	3.82e-07	1.26e-07	0.00488	2.93e-06	0.000235
Hansen–Sargan test statistic	0.208	0.293	1.507	0.542	1.879	0.356	1.006	0.0267
Hansen–Sargan *p*-value	0.649	0.588	0.681	0.462	0.170	0.550	0.316	0.870
Shea's partial R^2	0.163	0.445	0.303	0.296	0.0802	0.366	0.142	0.206
Kleibergen–Paap LM test statistic	16.97	42.38	32.53	32.70	10.51	36.33	15.00	19.07
Kleibergen–Paap *p*-value	0.000207	6.28e-10	1.49e-06	7.93e-08	0.00523	1.29e-08	0.000553	7.22e-05
Kleibergen–Paap *F*-statistic	12.47	48.32	17.31	25.71	7.482	24.32	11.80	8.660
Pesaran–Taylor reset statistic	5.471	0.00111	0.0912	0.0183	3.090	1.915	0.267	0.0880
Pesaran–Taylor *p*-value	0.0193	0.973	0.763	0.892	0.0788	0.166	0.605	0.767

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
HPG = HCHS, prescribing and GMS/PMS.

Note

All spend figures are on a net population basis and are adjusted for local prices using three MFFs from the Department of Health's resource allocation exposition book for 2009/10. All estimated models use 152 PCTs and are weighted by PCT population. The SYLLR is the mortality indicator. There are several differences between the models estimated here and those reported in Martin *et al.*:[59] (i) here we use net population spend data (not net spend data); (ii) here we use three MFFs (not solely the HCHS MFF); and (iii) here we use a consistent definition of the 'other programme need' proxy across all programmes (i.e. all-cause SYLLR minus the own programme SYLLR).

In all four outcome models expenditure has a significant negative effect on mortality and, in three of these, the all service measure of need has a significant positive effect. In the respiratory outcome model, where the all service need term is not significant, there is another indicator of need – the proportion of the population that are permanently sick – and this is both positive and statistically significant. The diagnostic statistics suggest that, in all four cases, own programme expenditure is endogenous and that the instruments are valid. They also suggest that the instruments are relevant. There is some evidence that the instruments are slightly weak in one of the four outcome results (the respiratory model).[ab] The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

In all four expenditure models both the need and budget variables have a positive and significant effect on own programme expenditure. In addition, the proxy for need in other programmes is negative and significant in all four cases. In the gastrointestinal expenditure programme the prevalence of lone pensioners households is associated with less NHS expenditure; there might be some unmet need here or perhaps this is a self-selecting group.

The diagnostic statistics suggest that, for all four expenditure models, the proxy for other programme need is endogenous and that the instruments are valid. They also suggest that the instruments are relevant and, with the possible exception of the gastrointestinal expenditure result, there is no evidence that the instruments are weak. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

The elasticities shown in *Table 59* can be used to calculate the cost of a life-year in each programme and these calculations – for both these four programmes as well as for the other six programmes with a mortality-based outcome indicator – are shown in *Tables 60* and *61* (the full outcome and expenditure models for the other six programmes with a mortality-based outcome indicator are not shown here).

Table 60 reveals that the cost of a life-year for the big four programmes combined is £11,298. This is remarkably close to the figure obtained using expenditure data for 2005/6, an AREA-based measure of need, and a HCHS MFF (£12,855). The cost of a life-year for all 10 programmes with a mortality-based measure of need is £21,743, which is even closer to the figure obtained using 2005/6 expenditure data (£21,256). If we assume a zero gain in the 13 programmes without a mortality-based indicator then the cost per life-year across all 23 programmes is £66,318 (it is £56,799 for 2005/6 data).

Alternatively, if we assume that PBC 23 generates a zero health gain and that the gain attributable to the remaining 12 programmes is, on average, the same as that attributable to those with a mortality outcome measure, then *Table 61* shows that the cost of a life-year across all programmes is £25,038 (it is £24,200 for 2005/6 data).

TABLE 60 Table showing cost of life and life-year estimates using spend data for 2006/7 (three MFFs) and outcome data for 2004/5/6 (assumes zero gain for 13 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Average annual mortality, < 75 years, 2004/5/6	(G) Outcome elasticity	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2004/5/6	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
1	Cancer	4122	0.542	22.34	62,259	0.351	118.44	188,625	2,221,530	1409	15,859
2	Circulatory problems	6161	0.694	42.76	45,504	1.441	455.06	93,959	1,463,912	4880	8762
3	Respiratory problems	3285	0.712	23.39	11,601	2.83	233.76	100,058	321,264	2158	10,839
4	Gastrointestinal problems	3700	0.65	24.05	5926	2.125	81.85	293,820	328,853	1514	15,884
5	Big four programmes	17,268		112.54	125,290		889.12	126,573	4,335,559	9961	11,298
6	*Big four programmes 2005/6*	*17,625*		*141.22*	*125,290*		*909.96*	*155,196*	*4,516,953*	*10,986*	*12,855*
7	Infectious diseases	1053	0.725	7.63	2050	0.03	0.45	17,121,951	101604	7	1,036,377
8	Endocrine problems	1852	0.954	17.67	1690	0.965	15.56	1,135,604	60,615	186	94,985
9	Neurological problems	2790	0.64	17.86	729	0.1	0.47	38,271,605	68,808	15	1,216,428
10	Genitourinary problems	3482	0.799	27.82	294	0.074	0.17	160,047,803	11,554	2	12,217,601
11	Trauma and injuries	2892	0.609	17.61	1037	0.527	3.33	5,291,867	30,000	32	548,767
12	Maternity and neonates	3574	0.601	21.48	2123	0.036	0.46	46,762,966	484,950	35	614,153
13	Other six programmes	15,643		110.07	7923		20.43	5,387,190	757,531	277	396,796

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Average annual mortality, < 75 years, 2004/5/6	(G) Outcome elasticity	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2004/5/6	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
14	*Other six programmes 2005/6*	*12,743*		*99.44*	*7923*		*16.26*	*6,115,621*	*751,009*	*337*	*295,074*
15	All 10 programmes	32,911	0.676	222.61	133,213		909.55	244,747	5,093,090	10,238	21,743
16	*All 10 programmes 2005/6*	*30,368*	*0.792*	*240.67*	*133,213*		*926.22*	*259,838*	*5,267,962*	*11,322*	*21,256*
Assume zero health gain in the other 13 programmes											
18	Other 13 programmes	34,985	1.304	456.35			0.00			0	
19	*Other 13 programmes 2005/6*	*33,942*	*1.186*	*402.43*			*0.00*			*0*	
20	All 23 programmes	67,896		678.96			909.55	746,481		10,238	66,318
21	*All 23 programmes 2005/6*	*64,310*		*643.10*			*926.22*	*694,330*		*11,322*	*56,799*

Note
Italicised text shows estimates reported previously in *Table 44*.
All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Annual mortality figures reported in cells F5 and F6 ,and F13 and F14 are identical because we do not have mortality data for 2002/3/4.
For 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.

TABLE 61 Table showing cost of life and life-year estimates using spend data for 2006/7 (three MFFs) and outcome data for 2004/5/6 (assumes some gain in other 13 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Average annual mortality, < 75 years, 2004/5/6	(G) Outcome elasticity	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2004/5/6	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
1	Cancer	4122	0.542	22.34	62,259	0.351	118.44	188,625	2,221,530	1409	15,859
2	Circulatory problems	6161	0.694	42.76	45,504	1.441	455.06	93,959	1,463,912	4880	8762
3	Respiratory problems	3285	0.712	23.39	11,601	2.83	233.76	100,058	321,264	2158	10,839
4	Gastrointestinal disease	3700	0.65	24.05	5926	2.125	81.85	293,820	328,853	1514	15,884
5	Big four programmes	17,268		112.54	125,290		889.12	126,573	4,335,559	9961	11,298
6	*Big four programmes 2005/6*	*17,625*		*141.22*	*125,290*		*909.96*	*155,196*	*4,516,953*	*10,986*	*12,855*
7	Infectious diseases	1053	0.725	7.63	2050	0.03	0.45	17,121,951	101604	7	1,036,377
8	Endocrine problems	1852	0.954	17.67	1690	0.965	15.56	1,135,604	60,615	186	94,985
9	Neurological problems	2790	0.64	17.86	729	0.1	0.47	38,271,605	68,808	15	1,216,428
10	Genitourinary problems	3482	0.799	27.82	294	0.074	0.17	160,047,803	11,554	2	12,217,601
11	Trauma and injuries	2892	0.609	17.61	1037	0.527	3.33	5,291,867	30,000	32	548,767
12	Maternity and neonates	3574	0.601	21.48	2123	0.036	0.46	46,762,966	484,950	35	614,153
13	Other six programmes	15,643		110.07	7923		20.43	5,387,190	757,531	277	396,796

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Average annual mortality, < 75 years, 2004/5/6	(G) Outcome elasticity	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2004/5/6	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
14	*Other six programmes 2005/6*	*12,743*		*99.44*	*7923*		*16.26*	*6,115,621*	*751,009*	*337*	*295,074*
15	All 10 programmes	32,911	0.676	222.61	133,213		909.55	244,747	5,093,090	10,238	21,743
16	*All 10 programmes 2005/6*	*30,368*	*0.792*	*240.67*	*133,213*		*926.22*	*259,838*	*5,267,962*	*11,322*	*21,256*
Assume zero health gain in PBC 23, and gain in 10 PBCs applies to other 12 PBCs											
17	PBC 23	10,585	0.844	89.34			0.00			0.00	
18	*PBC 23 2005/6*	*8449*	*0.926*	*78.24*			*0.00*			*0.00*	
19	Other 12 programmes	24,400		367.01			1499.56	244,747		16,880	21,743
20	*Other 12 programmes 2005/6*	*25,493*		*324.20*			*1247.69*	*259,838*		*15,252*	*21,256*
21	All 23 programmes	67,896		678.96			2409.11	281,830		27,118	25,038
22	*All 23 programmes 2005/6*	*64,310*		*643.10*			*2173.90*	*295,827*		*26,575*	*24,200*

Note
Italicised text shows estimates reported previously in *Table 44*.
All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Annual mortality figures reported in cells F5 and F6 ,and F13 and F14 are identical because we do not have mortality data for 2002/3/4.
For 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure

Model estimation using 2006/7 expenditure data and mortality data for 2004/5/6: CARAN need and two market forces factors

Further discussion by the project team noted that the PB data incorporates all PCT expenditure and that, as there is a separate category for GMS/PMS expenditure (PBC 23a), it seems appropriate that the GMS/PMS MFF should be applied to this category. However, other categories of expenditure exclude GMS/PMS expenditure but incorporate both HCHS and prescribing expenditure. It therefore seems appropriate that a weighted averaged of the HCHS and prescribing MFFs should be applied to these other (non-GMS/PMS) categories of expenditure.

We therefore re-estimated the outcome and expenditure models for those programmes with a mortality-based outcome indicator using the CARAN measure of need and adjusting expenditure for local input prices using the MFFs for HCHS and prescribing services. The outcome and expenditure results for the big four programmes are shown in *Table 62* with the relevant outcome and expenditure elasticities again highlighted (the first-stage regressions associated with these results can be found in *Table 95* in the *Annex*).

In all four outcome models expenditure has a significant negative effect on mortality and, in three of these, the all service measure of need has a significant positive effect. In the respiratory outcome model, where the all service need term is not significant, there is another indicator of need – the proportion of the population that are permanently sick – and this is both positive and statistically significant. The all service measure of need squared is also positive and significant in the cancer outcome equation. The diagnostic statistics suggest that, in all four cases, own programme expenditure is endogenous and that the instruments are valid. They also suggest that the instruments are relevant. There is a little evidence that the instruments are weak in one of the four outcome results, namely the respiratory model. Re-estimation of the latter model but without the least significant instrument generates a coefficient of –3.507 on expenditure and the Kleibergen–Paap *F*-statistic now exceeds 10 (it is 11.799). The Pesaran–Taylor test suggests that there is no evidence of model misspecification in any of the outcome models.

In all four expenditure models both the need and budget variables have a positive and significant effect on own programme expenditure. In addition, the proxy for need in other programmes is negative and significant in all four cases. In the gastrointestinal expenditure programme the prevalence of lone pensioners households is associated with less NHS expenditure; there might be some unmet need here or perhaps this is self-selecting group.

The diagnostic statistics suggest that, for all four expenditure models, expenditure is endogenous and the instruments are valid. They also suggest that the instruments are relevant and, with the possible exception of the gastrointestinal expenditure result, there is no evidence that the instruments are weak. Re-estimation of the gastrointestinal expenditure model without the least significant instrument generates a coefficient of 0.667 on the budget variable and the Kleibergen–Paap *F*-statistic now exceeds 10 (it is 16.871). The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

TABLE 62 Table showing outcome and expenditure models for the big four programmes using spend data for 2006/7 (incorporating two MFFs) and mortality data for 2004/5/6

	PBC 2, cancer, 2006/7		PBC 10, circulation, 2006/7		PBC 11, respiratory, 2006/7		PBC 13, gastrointestinal, 2006/7	
PBC scenario	(1) Outcome model	(2) Spend model	(3) Outcome model	(4) Spend model	(5) Outcome model	(6) Spend model	(7) Outcome model	(8) Spend model
Own programme spend per head	−0.337***		−1.447***		−2.839***		−2.137***	
	[0.104]		[0.220]		[0.772]		[0.569]	
Need CARAN per head	0.974***	1.772***	2.860***	2.191***	1.782	1.375***	4.657***	2.697***
	[0.110]	[0.287]	[0.257]	[0.355]	[1.198]	[0.297]	[0.716]	[0.676]
NeedCARAN per head squared	1.314***							
	[0.352]							
All-cause SYLLR excluding cancer		−0.951***						
		[0.180]						
PCT budget per head		0.548**		0.701**		0.718***		0.655**
		[0.242]		[0.292]		[0.253]		[0.289]
All-cause SYLLR excluding circulatory disease				−1.778***				
				[0.336]				
Permanently sick aged 16–74 years					1.385***			
					[0.405]			
All-cause SYLLR excluding respiratory problems						−0.663**		
						[0.288]		
All-cause SYLLR excluding gastrointestinal problems								−1.847***
								[0.609]

continued

TABLE 62 Table showing outcome and expenditure models for the big four programmes using spend data for 2006/7 (incorporating two MFFs) and mortality data for 2004/5/6 (*continued*)

	PBC 2, cancer, 2006/7		PBC 10, circulation, 2006/7		PBC 11, respiratory, 2006/7		PBC 13, gastrointestinal, 2006/7	
PBC scenario	(1) Outcome model	(2) Spend model	(3) Outcome model	(4) Spend model	(5) Outcome model	(6) Spend model	(7) Outcome model	(8) Spend model
Lone pensioner households								–0.590**
								[0.295]
Constant	6.506***	5.881***	11.567***	10.227***	19.047***	3.032	12.260***	9.664***
	[0.455]	[1.778]	[1.058]	[2.387]	[3.877]	[1.977]	[2.441]	[3.046]
Endogeneity test statistic	15.173	20.248	43.405	25.854	27.876	7.863	21.853	13.607
Endogeneity *p*-value	9.81e-05	6.80e-06	0	3.68e-07	1.29e-07	0.00505	2.94e-06	0.000225
Hansen–Sargan test statistic	0.00201	0.306	1.440	0.530	1.912	0.344	1.011	0.0294
Hansen–Sargan *p*-value	0.964	0.580	0.696	0.467	0.167	0.557	0.315	0.864
Shea's partial R^2	0.164	0.445	0.300	0.296	0.0793	0.366	0.140	0.206
Kleibergen–Paap LM test statistic	17.85	42.38	32.37	32.70	10.42	36.33	14.86	19.07
Kleibergen–Paap *p*-value	0.000133	6.28e-10	1.61e-06	7.93e-08	0.00545	1.29e-08	0.000592	7.22e-05
Kleibergen–Paap *F*-statistic	13.28	48.32	17.14	25.71	7.390	24.32	11.63	8.660
Pesaran–Taylor reset statistic	0.00226	0.00178	0.0945	0.0215	3.139	1.908	0.266	0.0605
Pesaran–Taylor *p*-value	0.962	0.966	0.759	0.883	0.0764	0.167	0.606	0.806

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.

The outcome and expenditure elasticities are little changed from those presented *in Table 59* and, like those, these new elasticities can be used to calculate the cost of a life-year in each programme. These calculations – for both these four programmes as well as for the other six programmes with a mortality-based outcome indicator – are shown in *Tables 63* and *64* (the full outcome and expenditure models for the other six programmes with a mortality-based outcome indicator are not shown here).

The figures for 2006/7 in *Table 63* (which incorporate two MFFs) can be compared with those for 2006/7 in *Table 60* (which incorporate three MFFs). *Table 63* reveals that the use of a different MFF has little impact on the cost of a life-year for the big four PBCs (it was £11,298, it is now £10,783) as well as on the cost of a life-year for all programmes with a mortality outcome measure (it was £21,743, it is now £20,893).

In addition, *Table 64* shows that if we assume that PBC 23 generates a zero health gain and that the gain attributable to the remaining 12 programmes is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes is now £23,697 (it was £25,038 for 2006/7 in *Table 61*).

The figures in *Table 64* also reveal that the cost of a life-year in 2006/7 for all programmes (£23,697) is little changed from the comparable figure for 2005/6 (£24,200).

Model estimation using 2006/7 expenditure data and mortality data for 2006/7/8: CARAN need and two market forces factors

One shortcoming with the models presented above is that they relate expenditure in 2006/7 to mortality in the same period and in the two previous periods (i.e. in 2004, 2005 and 2006). The difficulty with this is that one would expect expenditure in year t to affect mortality in year t and possibly *subsequent* years ($t+1$, $t+2$, etc.) but not mortality in *previous* years ($t-1$, $t-2$, etc.). However, if we assume that PCTs have reached some sort of equilibrium in the expenditure choices they make and the outcomes they secure, so that expenditure levels change relatively little from one year to the next, then mortality over the 3-year period t, $t-1$ and $t-2$ might be a good proxy for mortality in t, $t+1$ and $t+2$. Indeed, this is probably not an unreasonable assumption given the relatively slow pace at which both types of variable change.

Although this assumption of equilibrium is not an unreasonable one, it is one that ideally we would like to be able to drop. Fortunately, with the recent availability of more up-to-date mortality data, we have the opportunity to relate expenditure in 2006 to mortality in the same year and in the two following years (i.e. in 2006, 2007 and 2008).[ac] Thus, the models reported in *Table 62* were re-estimated replacing the mortality rate for 2004/5/6 with that for 2006/7/8. The outcome and expenditure results for the big four programmes are shown in *Table 65* with the relevant outcome and expenditure elasticities again highlighted (the first-stage regressions associated with these results can be found in *Table 96* in the *Annex*). These elasticities are similar to those presented previously in *Table 62* but there are some changes (e.g. the outcome elasticity in the respiratory outcome equation falls from –2.839 to –2.029).

In all four outcome models expenditure has a significant negative effect on mortality and the all service measure of need has a significant positive effect. The all service measure of need squared is also positive and significant in the cancer outcome equation. In the respiratory outcome model, there is an additional indicator of need – the proportion of the population that are permanently sick – and this is both positive and statistically significant. The diagnostic statistics suggest that, in all four cases, own programme expenditure is endogenous and that the instruments are valid. They also suggest that the instruments are relevant. There is no evidence that the instruments are weak in three of the four outcome results. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

TABLE 63 Table showing cost of life and life-year estimates using spend data for 2006/7 (two MFFs) and outcome data for 2004/06 (assumes zero gain for 13 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Average annual mortality, < 75 years, 2004/5/6	(G) Outcome elasticity	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2004/5/6	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
1	Cancer	4122	0.548	22.59	62,259	0.337	114.98	196,461	2,221,530	1368	16,518
2	Circulatory problems	6161	0.701	43.19	45,504	1.447	461.57	93,569	1,463,912	4950	8725
3	Respiratory problems	3285	0.718	23.59	11,601	3.507	292.12	80,743	321,264	2697	8747
4	Gastrointestinal problems	3700	0.667	24.68	5926	2.137	84.47	292,170	328,853	1562	15,795
5	Big four programmes	17,268		114.04	125,290		953.13	119,650	4,335,559	10,576	10,783
6	*Big four programmes 2005/6*	*17,625*		*141.22*	*125,290*		*909.96*	*155,196*	*4,516,953*	*10,986*	*12,855*
7	Infectious diseases	1053	0.731	7.70	2050	0.03	0.45	17,121,951	101,604	7	1,036,377
8	Endocrine problems	1852	0.966	17.89	1690	0.812	13.26	1,349,579	60,615	158	112,882
9	Neurological problems	2790	0.648	18.08	729	0.098	0.46	39,052,658	68,808	15	1,241,253
10	Genitourinary problems	3482	0.837	29.14	294	0.073	0.18	162,240,239	11,554	2	12,384,965
11	Trauma and injuries	2892	0.617	17.84	1037	0.527	3.37	5,291,867	30,000	33	548,767
12	Maternity and neonates	3574	0.601	21.48	2123	0.035	0.45	48,099,051	484,950	34	631,700
13	Other six programmes	15,643		112.13	7923		18.17	6,172,491	757,531	249	449,706
14	*Other six programmes 2005/6*	*12,743*		*99.44*	*7923*		*16.26*	*6,115,621*	*751,009*	*337*	*295,074*
15	All 10 programmes	32,911	0.687	226.18	133,213		971.30	232,861	5,093,090	10,826	20,893
16	*All 10 programmes 2005/6*	*30,368*	*0.792*	*240.67*	*133,213*		*926.22*	*259,838*	*5,267,962*	*11,322*	*21,256*

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Average annual mortality, < 75 years, 2004/5/6	(G) Outcome elasticity	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2004/5/6	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
Assume zero health gain in the other 13 programmes											
18	Other 13 programmes	34,985	1.294	452.78			0.00			0	
19	*Other 13 programmes 2005/6*	*33,942*	*1.186*	*402.43*			*0.00*			*0*	
20	All 23 programmes	67,896		678.96			971.30	699,024		10,826	62,718
21	*All 23 programmes 2005/6*	*64,310*		*643.10*			*926.22*	*694,330*		*11,322*	*56,799*

Note
Italicised text shows estimates reported previously in *Table 44*.
All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Annual mortality figures reported in cells F5 and F6 ,and F13 and F14 are identical because we do not have mortality data for 2002/3/4.
For 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.

TABLE 64 Table showing cost of life and life-year estimates using spend data for 2006/7 (two MFFs) and outcome data for 2004/06 (assumes some gain in other 13 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Average annual mortality, < 75 years, 2004/5/6	(G) Outcome elasticity	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2004/5/6	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
1	Cancer	4122	0.548	22.59	62,259	0.337	114.98	196,461	2,221,530	1368	16,518
2	Circulatory problems	6161	0.701	43.19	45,504	1.447	461.57	93,569	1,463,912	4950	8725
3	Respiratory problems	3285	0.718	23.59	11,601	3.507	292.12	80,743	321,264	2697	8747
4	Gastrointestinal problems	3700	0.667	24.68	5926	2.137	84.47	292,170	328,853	1562	15,795
5	Big four programmes	17,268		114.04	125,290		953.13	119,650	4,335,559	10,576	10,783
6	*Big four programmes 2005/6*	*17,625*		*141.22*	*125,290*		*909.96*	*155,196*	*4,516,953*	*10,986*	*12,855*
7	Infectious diseases	1053	0.731	7.70	2050	0.03	0.45	17,121,951	101,604	7	1,036,377
8	Endocrine problems	1852	0.966	17.89	1690	0.812	13.26	1,349,579	60,615	158	112,882
9	Neurological problems	2790	0.648	18.08	729	0.098	0.46	39,052,658	68,808	15	1,241,253
10	Genitourinary problems	3482	0.837	29.14	294	0.073	0.18	162,240,239	11,554	2	12,384,965
11	Trauma and injuries	2892	0.617	17.84	1037	0.527	3.37	5,291,867	30,000	33	548,767
12	Maternity and neonates	3574	0.601	21.48	2123	0.035	0.45	48,099,051	484,950	34	631,700
13	Other six programmes	15,643		112..13	7923		18.17	6,172,491	757,531	249	449,706

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Average annual mortality, < 75 years, 2004/5/6	(G) Outcome elasticity	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2004/5/6	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
14	*Other six programmes 2005/6*	*12,743*		*99.44*	*7923*		*16.26*	*6,115,621*	*751,009*	*337*	*295,074*
15	All 10 programmes	32,911	0.687	226.18	133,213		971.30	232,861	5,093,090	10,826	20,893
16	*All 10 programmes 2005/6*	*30,368*	*0.792*	*240.67*	*133,213*		*926.22*	*259,838*	*5,267,962*	*11,322*	*21,256*
Assume zero health gain in PBC 23, and gain in 10 PBCs applies to other 12 PBCs											
17	PBC 23	10,585	0.759	80.34			0.00			0.00	
18	*PBC 23 2005/6*	*8449*	*0.926*	*78.24*			*0.00*			*0.00*	
19	Other 12 programmes	24,400		372.44			1,599.42	232,861		17,826	20,893
20	*Other 12 programmes 2005/6*	*25,493*		*324.20*			*1,247.69*	*259,838*		*15,252*	*21,256*
21	All 23 programmes	67,896		678.96			2,570.72	264,113		28,652	23,697
22	*All 23 programmes 2005/6*	*64,310*		*643.10*			*2,173.90*	*295,827*		*26,575*	*24,200*

Note
Italicised text shows estimates reported previously in *Table 44*.
All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Annual mortality figures reported in cells G5 and G6 ,and G13 and G14 are identical because we do not have mortality data for 2002/3/4.
For 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.

TABLE 65 Table showing outcome and expenditure models for the big four programmes using spend data for 2006/7 (two MFFs) and mortality data for 2006/7/8

	PBC 2 cancer		PBC 10 circulation		PBC 11 respiratory		PBC 13 gastrointestinal	
Variable	(1) Outcome model	(2) Spend model	(3) Outcome model	(4) Spend model	(5) Outcome model	(6) Spend model	(7) Outcome model	(8) Spend model
Own programme spend per head	−0.342***		−1.434***		−2.029***		−1.536***	
	[0.099]		[0.218]		[0.636]		[0.468]	
Need CARAN per head	0.995***	1.626***	2.860***	2.306***	2.696***	1.449***	4.160***	2.040***
	[0.106]	[0.343]	[0.252]	[0.372]	[1.044]	[0.331]	[0.577]	[0.378]
Need CARAN per head squared	1.163***				2.451			
	[0.348]				[1.561]			
SYLLR all deaths excluding cancer		−0.855***						
		[0.191]						
PCT budget per head		0.465		0.540*		0.679***		0.446*
		[0.300]		[0.299]		[0.251]		[0.263]
SYLLR all deaths excluding circulatory				−1.666***				
				[0.295]				
Permanently sick					0.759**			
					[0.367]			
SYLLR all deaths excluding respiratory						−0.672**		
						[0.305]		
SYLLR all deaths excluding gastrointestinal								−1.206***
								[0.314]
Lone pensioner households								

Variable	PBC 2 cancer		PBC 10 circulation		PBC 11 respiratory		PBC 13 gastrointestinal	
	(1) Outcome model	(2) Spend model	(3) Outcome model	(4) Spend model	(5) Outcome model	(6) Spend model	(7) Outcome model	(8) Spend model
Constant	6.501***	5.913***	11.413***	10.696***	13.756***	3.346	9.719***	8.370***
	[0.436]	[2.815]	[1.046]	[2.379]	[3.279]	[2.075]	[2.009]	[2.299]
Endogeneity test statistic	13.695	19.421	42.548	24.461	17.687	8.439	16.373	15.211
Endogeneity *p*-value	0.000215	1.05e-05	6.90e-11	7.58e-07	2.60e-05	0.00367	5.20e-05	9.61e-05
Hansen–Sargan test statistic	0.685	0.021	0.949	1.262	1.462	0.302	2.761	0.0164
Hansen–Sargan *p*-value	0.408	0.084	0.814	0.261	0.227	0.583	0.0966	0.0898
Shea's partial R^2	0.164	0.445	0.300	0.296	0.0785	0.327	0.140	0.356
Kleibergen–Paap LM test statistic	17.85	41.88	32.37	32.02	10.02	34.98	14.86	35.72
Kleibergen–Paap *p*-value	0.000133	8.04e-10	1.61e-06	1.11e-07	0.00666	2.54e-08	0.000592	1.75e-08
Kleibergen–Paap *F*-statistic	13.28	56.69	17.14	31.84	7.022	20.94	11.63	22.40
Pesaran–Taylor reset statistic	0.00537	0.18	0.136	0.00349	0.0120	1.497	1.669	0.007
Pesaran–Taylor *p*-value	0.942	0.668	0.712	0.953	0.913	0.221	0.196	0.935

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.

However, the Kleibergen–Paap *F*-statistic for the respiratory disease outcome model is 7.022 and this is less than the 'critical' target of 10.0. This indicates that the instruments may be weak. However, if we re-estimate this model having dropped the least significant instrument, the coefficient on own programme expenditure is now –2.622 and this is significant at the 1% level. Moreover, there is now no evidence of weak instruments (the Kleibergen–Paap *F*-statistic is 11.025) and it is this coefficient that we use for the respiratory outcome model in the cost of a life-year calculations below.

In three of the four expenditure models both the need and budget variables have a positive and significant effect on own programme expenditure. In addition, the proxy for need in other programmes is negative and significant in all four cases. The diagnostic statistics suggest that, for all four expenditure models, expenditure is endogenous and the instruments are valid. They also suggest that the instruments are relevant and there is no evidence that the instruments are weak. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

The outcome and expenditure elasticities presented in *Table 65* can be used to calculate the cost of a life-year in each programme. These calculations – for both the big four programmes as well as for the other six programmes with mortality-based outcome indicators – are shown in *Table 66*. They show that the use of a more appropriate measure of mortality (i.e. for 2006/7/8 rather than for 2004/5/6) slightly increases the cost of a life-year for the big four PBCs (from £10,783 to £12,333) as well as for all 10 programmes with a mortality outcome measure (from £20,893 to £23,780).

In addition, *Table 67* shows that if we assume that PBC 23 generates a zero health gain and that the gain attributable to the remaining 12 programmes is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes is now £26,876 (it was £23,697 using mortality for 2004/5/6).

TABLE 66 Table showing cost of life and life-year estimates using spend data for 2006/7 and outcome data for 2006/7/8 (assumes zero health gain for 13 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2006/7/8	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
1	Cancer	4122	0.465	19.17	61,961	0.342	98.54	194,520	2,207,021	1170	16,383
2	Circulatory problems	6161	0.540	33.27	41,106	1.434	318.31	104,519	1,361,634	3515	9466
3	Respiratory problems	3285	0.679	22.31	11,574	2.622	206.06	108,248	324,223	1924	11,593
4	Gastrointestinal problems	3700	0.446	16.50	6160	1.536	42.20	391,048	345,908	790	20,892
Big four programmes summary											
5	Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801		665.10	137,188	4,238,786	7399	12,333
6[a]	*Spend 2006 and mortality 2004/5/6*	*17,268*		*114.04*	*125,290*		*953.13*	*119,650*	*4,335,559*	*10,576*	*10,783*
7[b]	*Spend 2005 and mortality 2002/3/4*	*17,625*		*141.22*	*125,290*		*909.96*	*155,196*	*4,516,953*	*10,986*	*12,855*
8	Infectious diseases	1053	0.792	8.34	2050	0.047	0.76	10,928,905	106,552	13	630,798
9	Endocrine problems	1852	0.953	17.65	1542	0.842	12.37	1,426,410	57,672	154	114,416
10	Neurological problems	2790	0.616	17.19	727	0.112	0.50	34,265,082	66,137	15	1,129,960

continued

TABLE 66 Table showing cost of life and life-year estimates using spend data for 2006/7 and outcome data for 2006/7/8 (assumes zero health gain for 13 programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2006/7/8	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
11	Genitourinary problems	3482	0.912	31.76	294	0.051	0.14	232,226,224	10,030	2	20,421,090
12	Trauma and injuries	2892	0.358	10.35	1037	0	0.00	N/A	30,000	0	N/A
13	Maternity and neonates	3574	0.224	8.01	2189	0.482	2.36	3,387,363	492,600	177	45,158
Other six programmes summary											
14	Spend 2006 and mortality 2006/7/8	15,643		93.29	7839		16.14	5,780,723	762,991	362	258,046
15[a]	*Spend 2006 and mortality 2004/5/6*	*15,643*		*112.13*	*7923*		*18.17*	*6,172,491*	*757,531*	*249*	*449,706*
16[b]	*Spend 2005 and mortality 2002/3/4*	*12,743*		*99.44*	*7923*		*16.26*	*6,115,621*	*751,009*	*337*	*295,074*
All 10 programmes summary											
17	Spend 2006 and mortality 2006/7/8	32,911	0.561	184.53	128,640		681.24	270,881	5,001,777	7760	23,780
18[a]	*Spend 2006 and mortality 2004/5/6*	*32,911*	*0.687*	*226.18*	*133,213*		*971.30*	*232,861*	*5,093,090*	*10,826*	*20,893*
19[b]	*Spend 2005 and mortality 2002/3/4*	*30,368*	*0.792*	*240.67*	*133,213*		*926.22*	*259,838*	*5,267,962*	*11,322*	*21,256*

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2006/7/8	(K) (= 0.01 × D × G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
Assume zero health gain in the other 13 programmes: other 13 programmes summary											
20	Spend 2006 and mortality 2006/7/8	*34,985*	1.413	494.43			0.00			0	
21[a]	*Spend 2006 and mortality 2004/5/6*	*34,985*	*1.294*	*452.78*			*0.00*			*0*	
22[b]	*Spend 2005 and mortality 2002/3/4*	*33,942*	*1.186*	*402.43*			*0.00*			*0*	
All 23 programmes											
23	Spend 2006 and mortality 2006/7/8	67,896		678.96			681.24	996,655		7760	87,494
24[a]	*Spend 2006 and mortality 2004/5/6*	*67,896*		*678.96*			*971.30*	*699,024*		*10,826*	*62,718*
25[b]	*Spend 2005 and mortality 2002/3/4*	*64,310*		*643.10*			*926.22*	*694,330*		*11,322*	*56,799*

N/A, not applicable.
a Estimate reported previously in *Table 63*.
b Estimate reported previously in *Table 44*.
Note
All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Annual mortality figures reported in cells F6 and F7, and F15 and F16 are identical because we do not have mortality data for 2002/3/4.
We have been unable to obtain a satisfactory outcome model for trauma and injuries and have assumed a zero outcome elasticity.
For expenditure in 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.

TABLE 67 Table showing cost of life and life-year estimates using spend data for 2006/7 and outcome data for 2006/7/8 (assumes average health gain for 12 other programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2006/7/8	(K) (= 0.01 × D× G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
1	Cancer	4122	0.465	19.17	61,961	0.342	98.54	194,520	2,207,021	1170	16,383
2	Circulatory problems	6161	0.540	33.27	41,106	1.434	318.31	104,519	1,361,634	3515	9466
3	Respiratory problems	3285	0.679	22.31	11,574	2.622	206.06	108,248	324,223	1924	11,593
4	Gastrointestinal problems	3700	0.446	16.50	6160	1.536	42.20	391,048	345,908	790	20,892
Big four programmes summary											
5	Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801		665.10	137,188	4,238,786	7399	12,333
6[a]	*Spend 2006 and mortality 2004/5/6*	*17,268*		*114.04*	*125,290*		*953.13*	*119,650*	*4,335,559*	*10,576*	*10,783*
7[b]	*Spend 2005 and mortality 2002/3/4*	*17,625*		*141.22*	*125,290*		*909.96*	*155,196*	*4,516,953*	*10,986*	*12,855*
8	Infectious diseases	1053	0.792	8.34	2050	0.047	0.76	10,928,905	106,552	13	630,798
9	Endocrine problems	1852	0.953	17.65	1542	0.842	12.37	1,426,410	57,672	154	114,416
10	Neurological problems	2790	0.616	17.19	727	0.112	0.50	34,265,082	66,137	15	1,129,960
11	Genitourinary problems	3482	0.912	31.76	294	0.051	0.14	232,226,224	10,030	2	20,421,090

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2006/7/8	(K) (= 0.01 × D× G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
12	Trauma and injuries	2892	0.358	10.35	1037	0	0.00	N/A	30,000	0	N/A
13	Maternity and neonates	3574	0.224	8.01	2189	0.482	2.36	3,387,363	492,600	177	45,158
Other six programmes summary											
14	Spend 2006 and mortality 2006/7/8	15,643		93.29	7839		16.14	5,780,723	762,991	362	258,046
15[a]	*Spend 2006 and mortality 2004/5/6*	*15,643*		*112.13*	*7923*		*18.17*	*6,172,491*	*757,531*	*249*	*449,706*
16[b]	*Spend 2005 and mortality 2002/3/4*	*12,743*		*99.44*	*7923*		*16.26*	*6,115,621*	*751,009*	*337*	*295,074*
All 10 programmes summary											
17	Spend 2006 and mortality 2006/7/8	32,911	0.561	184.53	128,640		681.24	270,881	5,001,777	7760	23,780
18[a]	*Spend 2006 and mortality 2004/5/6*	*32,911*	*0.687*	*226.18*	*133,213*		*971.30*	*232,861*	*5,093,090*	*10,826*	*20,893*
19[b]	*Spend 2005 and mortality 2002/3/4*	*30,368*	*0.792*	*240.67*	*133,213*		*926.22*	*259,838*	*5,267,962*	*11,322*	*21,256*

continued

TABLE 67 Table showing cost of life and life-year estimates using spend data for 2006/7 and outcome data for 2006/7/8 (assumes average health gain for 12 other programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2006/7/8	(K) (= 0.01 × D× G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
Other 13 PBCs? Assume zero health gain in PBC 23 . . .											
20	PBC 23: spend 2006 and mortality 2006/7/8	10,585	0.739	78.22			0.00			0.00	
21	PBC 23: spend 2006 and mortality 2004/5/6	10,585	0.759	80.34			0.00			0.00	
22	PBC 23: spend 2005 and mortality 2002/3/4	*8449*	*0.926*	*78.24*			*0.00*			*0.00*	
. . . and that the gain in 10 PBCs (see above) applies to the remaining 12 PBCs											
23	12 PBCs: spend 2006 and mortality 2006/7/8	24,400		416.20			1536.48	270,881		17,502	23,780
24[a]	*12 PBCs: spend 2006 and mortality 2004/5/6*	*24,400*		*372.44*			*1599.42*	*232,861*		*17,826*	*20,893*
25[b]	*12 PBCs: spend 2005 and mortality 2002/3/4*	*25,493*		*324.20*			*1247.69*	*259,838*		*15,252*	*21,256*

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)	(J) Total life-years lost, < 75 years, 2006/7/8	(K) (= 0.01 × D× G × J/3) change in annual life-years lost	(L) (= E/K) cost per YLG (£)
All 23 programmes											
26	23 PBCs: spend 2006 and mortality 2006/7/8	67,896		678.96			2217.72	306,153		25,262	26,876
27[a]	*All 23 PBCs: spend 2006 and mortality 2004/5/6*	*67,896*		*678.96*			*2570.72*	*264,113*		*28,652*	*23,697*
28[b]	*All 23 PBCs: spend 2005 and mortality 2002/3/4*	*64,310*		*643.10*			*2173.90*	*295,827*		*26,575*	*24,200*

N/A, not applicable.
a Estimate reported previously in *Table 63*.
b Estimate reported previously in *Table 44*.
Note
All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Annual mortality figures reported in cells F5 and F6, and F13 and F14 are identical because we do not have mortality data for 2002/3/4.
For expenditure in 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.

Adjusting the cost of life (year) estimates for the mismatch in the ICD-10 coverage of the expenditure and the mortality data

The cost of a life (year) estimates presented in *Tables 66* and *67* assume a 1% increase in each PCT's budget and are calculated as:

the cost of an additional life in a particular programme

= the change in expenditure in that programme/the change in mortality in that programme

= (annual spend × expenditure elasticity)/(annual mortality × outcome elasticity × expenditure elasticity)

and

the cost of an additional life-year in a particular programme

= the change in expenditure in that programme/the change in life-year lost in that programme

= (annual spend × expenditure elasticity)/(annual mortality × outcome elasticity × expenditure elasticity)

Thus, an integral part of the calculation of the cost of a life (year) is the annual mortality (life-years lost) figure associated with a particular programme. Ideally, the ICD-10 coverage of the expenditure data should coincide with that of the mortality data but, as we know from *Table 37*, the ICD-10 coverage of the mortality data typically falls short of that for the expenditure data. Unless we adjust the annual mortality figure so that its ICD-10 coverage approximates that of the expenditure data, our cost of life (year) estimates will usually be too large because they will usually underestimate the mortality gain.

Table 68 reproduces *Table 66* but incorporates this ICD-10 coverage adjustment [see columns (J) and (O) in *Table 68*]. This adjustment reduces the cost of a life-year:

- for the big four programmes from £12,333 to £10,604
- for the 10 programmes with a mortality-based outcome indicator from £23,780 to £19,965
- for all programmes assuming a zero gain for the 13 PBCs without an outcome indicator from £87,494 to £73,457.

Similarly, *Table 69* reproduces *Table 67* but incorporates this ICD-10 coverage adjustment [see columns (J) and (O) in *Table 69*]. If we assume a zero health gain in PBC 23 and an average gain in the other 12 PBCs without a mortality-based outcome indicator, then this adjustment reduces the cost of a life-year for all programmes from £26,876 to £22,565.

Adjusting the cost of life (year) estimates for Department of Health-funded expenditure that is not undertaken by primary care trusts

Primary care trust expenditure accounts for a large proportion of Department of Health expenditure but PCTs do not account for all of the Department of Health's budget. In 2006/7 the Department of Health's gross expenditure totalled £83.5B. Charges raised £3.4B so net expenditure totalled £80.1B. Of this net expenditure, PCTs accounted for £67.3B (that is, 84%) and various other bodies accounted for the remaining £12.8B. A breakdown of this gross and net expenditure by major body is shown in *Table 70*.

The Department of Health has allocated net non-PCT expenditure across the 23 PBCs and the impact of this allocation on total spend by PBC is shown in *Table 71*. No geographic breakdown (e.g. by PCT) of this expenditure is available.

Of the additional £12B of net expenditure, £11.2B (93%) has been allocated to PBC 23. This largely reflects (a) the allocation of almost all SHA expenditure to either PBC 23B ('other: SHAs including workforce development committees') or PBC 23X ('other: miscellaneous'); and (b) the allocation of almost two-thirds of Department of Health expenditure to PBC 23X ('other: miscellaneous').

The remaining £0.8B of additional net expenditure is spread across all PBCs according to various allocation rules. For example, the majority of expenditure on Special Health Authorities is apportioned across programme categories on the basis of the PCT and SHA expenditure breakdown. The exception is the NHS Business Services Authority expenditure which is apportioned on the basis of primary care prescribing expenditure splits. Although this approach avoids allocating expenditure to the 'other: miscellaneous' category, this allocation of expenditure does not necessarily reflect actual expenditure. For example, NHS Litigation Authority expenditure may not be incurred in the same areas as overall PCT expenditure.[34]

It is clear that most of the non-PCT expenditure is not specific to any disease area and that, to avoid putting all of it into a residual category, the Department of Health has identified what are reasonable, but largely arbitrary, rules to spread what is a relatively small proportion of this non-PCT expenditure across all PBCs.

The cost of a life (year) estimates presented above are based on the impact of a 1% exogenous change in total net PCT spend. All of our outcome and expenditure models have been estimated using net PCT expenditure, and all of our elasticities relate to this expenditure. Implicitly we assume that any budgetary shock only affects PCT funding and that it leaves non-PCT funding unchanged.

Suppose instead we assume a 1% exogenous change in the Departmental budget. How might this budgetary shock be split between PCT and non-PCT expenditure? There are two obvious options to consider. We could assume either (a) that all of this change is applied to PCT budgets and that there is no change in the non-PCT budget (as we do implicitly at the moment); or (b) that the budgetary shock affects both PCT and non-PCT budgets.

If the non-PCT budget is wholly unresponsive to the exogenous shock then our cost of a life-year estimates will be unchanged because this expenditure category attracts none of the budgetary change (although this expenditure will clearly contribute to a measure of average productivity).

If the non-PCT budget is to some degree responsive to the exogenous shock then it will affect our cost of a life-year estimates. To calculate the size of this impact we would need to know:

(a) how responsive the non-PCT budget is to a total Departmental budgetary shock
(b) how the responsive part of the non-PCT budget is allocated across PBCs; and
(c) the size of the health effects associated with changes in the non-PCT budget at PBC level.

We have no evidence on how responsive the non-PCT budget is likely to be to a total budgetary shock. However, from *Table 71* and the discussion about the rather arbitrary (but understandable) rules employed by the Department of Health to allocate non-PCT expenditure to PBCs, it would seem reasonable to assume that any change in the non-PCT budget should all be allocated to PBC 23. This 'solves' the problem of identifying the health gains associated with this change in the non-PCT budget because, in our cost of a life-year calculations, we assume that expenditure in this category attracts no health gains.

Thus, although we have no evidence on how responsive the non-PCT budget is likely to be to a total budgetary shock, we can present two scenarios. In the first scenario, the non-PCT budget is wholly unresponsive to a budgetary shock and any budgetary change is fully implemented via PCT expenditure. In this case, there is no impact on the cost of a life-year.

In the second scenario, one might assume that the non-PCT budget is as responsive to Departmental budgetary changes as is the PCT budget. In this case a 1% change in the Departmental budget is translated into a 1% change in both the total PCT and total non-PCT budgets, and this will increase the cost of a life-year by 17.7% for 2006/7, that is, from £22,565 to £26,553. This percentage increase is, of course, the same figure as total non-PCT expenditure expressed as a percentage of PCT expenditure.

TABLE 68 Table showing cost of life and life-year estimates using expenditure data for 2006 and outcome data for 2006/7/8 (assumes zero health gain for 13 programmes) adjusted for the ICD-10 coverage of the expenditure and outcome data

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F)Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
1	Cancer	4122	0.465	19.17	61,961	0.342	98.54	194,520
2	Circulatory problems	6161	0.540	33.27	41,106	1.434	318.31	104,519
3	Respiratory problems	3285	0.679	22.31	11,574	2.622	206.06	108,248
4	Gastrointestinal problems	3700	0.446	16.50	6160	1.536	42.20	391,048
Big four programmes summary								
5	Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801		665.10	137,188
6	Spend 2006 and mortality 2004/5/6	17,268		114.04	125,290		953.13	119,650
7	Spend 2005 and mortality 2002/3/4	17,625		141.22	125,290		909.96	155,196
8	Infectious diseases	1053	0.792	8.34	2050	0.047	0.76	10,928,905
9	Endocrine problems	1852	0.953	17.65	1542	0.842	12.37	1,426,410
10	Neurological problems	2790	0.616	17.19	727	0.112	0.50	34,265,082
11	Genitourinary problems	3482	0.912	31.76	294	0.051	0.14	232,226,224
12	Trauma and injuries	2892	0.358	10.35	1037	0	0.00	N/A
13	Maternity and neonates	3574	0.224	8.01	2189	0.482	2.36	3,387,363
Other six programmes summary								
14	Spend 2006 and mortality 2006/7/8	15,643		93.29	7839		16.14	5,780,723
15	Spend 2006 and mortality 2004/5/6	15,643		112.13	7923		18.17	6,172,491
16	Spend 2005 and mortality 2002/3/4	12,743		99.44	7923		16.26	6,115,621

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2006/7/8	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for YLL	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) Cost per YLG adjusted for YLL coverage (£)
0.984	100.14	191,407	2,207,021	1170	0.984	1189	16,383	16,121
0.992	320.88	103,683	1,361,634	3515	0.992	3543	9466	9390
0.773	262.57	83,676	324,223	1924	0.773	2489	11,593	8961
0.571	73.90	223,288	345,908	790	0.571	1383	20,892	11,929
	761.49	119,823	4,238,786	7399		8604	12,333	10,604
			4,335,559	10,576			10,783	
			4,516,953	10,986			12,855	
1.000	0.76	10,928,905	106,552	13	1.000	13	630,798	630,798
0.634	19.52	904,344	57,672	154	0.634	243	114,416	72,539
0.136	3.69	4,660,051	66,137	15	0.136	112	1,129,960	153,675
0.172	0.80	39,942,910	10,030	2	0.172	9	20,421,090	3,512,427
0.175	0.00	N/A	30,000	0	0.175	0	N/A	N/A
8.213	0.29	27,820,413	492,600	177	0.679	261	45,158	30,662
	25.05	3,724,129	762,991	362		639	258,046	146,108
			757,531	249			449,706	
			751,009	337			295,074	

TABLE 68 Table showing cost of life and life-year estimates using expenditure data for 2006 and outcome data for 2006/7/8 (assumes zero health gain for 13 programmes) adjusted for the ICD-10 coverage of the expenditure and outcome data (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F)Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
All 10 programmes summary								
17	Spend 2006 and mortality 2006/7/8	32,911	0.561	184.53	128,640		681.24	270,881
18	Spend 2006 and mortality 2004/5/6	32,911	0.687	226.18	133,213		971.30	232,861
19	Spend 2005 and mortality 2002/3/4	30,368	0.792	240.67	133,213		926.22	259,838
Assume zero health gain in the other 13 programmes: other 13 programmes summary								
20	Spend 2006 and mortality 2006/7/8	34,985	1.413	494.43			0.00	
21	Spend 2006 and mortality 2004/5/6	34,985	1.294	452.78			0.00	
22	Spend 2005 and mortality 2002/3/4	33,942	1.186	402.43			0.00	
All 23 programmes								
23	Spend 2006 and mortality 2006/7/8	67,896		678.96			681.24	996,655
24	Spend 2006 and mortality 2004/5/6	67,896		678.96			971.30	699,024
25	Spend 2005 and mortality 2002/3/4	64,310		643.10			926.22	694,330

N/A, not applicable.

Note

All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Annual mortality figures reported in cells F6 and F7, and F15 and F16 are identical because we do not have mortality data for 2002/3/4.
We have been unable to obtain a satisfactory outcome model for trauma and injuries and have assumed a zero outcome elasticity.
For expenditure in 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.
The adjustment for the coverage of the YLL data relative to the spend data uses deaths under age 75 years in England in 2008.

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2006/7/8	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for YLL	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) Cost per YLG adjusted for YLL coverage (£)
	786.54	234,617	5,001,777	7760		9243	23,780	19,965
			5,093,090	10,826			20,893	
			5,267,962	11,322			21,256	
				0		0		
				0				
				0				
	786.54	863,228		7760		9243	87,494	73,457
				10,826			62,718	
				11,322			56,799	

TABLE 69 Table showing cost of life and life-year estimates using expenditure data for 2006 and outcome data for 2006/7/8 (assumes average health gain for 12 other programmes) adjusted for the ICD-10 coverage of the expenditure and outcome data

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
1	Cancer	4122	0.465	19.17	61,961	0.342	98.54	194,520
2	Circulatory problems	6161	0.540	33.27	41,106	1.434	318.31	104,519
3	Respiratory problems	3285	0.679	22.31	11,574	2.622	206.06	108,248
4	Gastrointestinal problems	3700	0.446	16.50	6160	1.536	42.20	391,048
Big four programmes summary								
5	Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801		665.10	137,188
6	Spend 2006 and mortality 2004/5/6	17,268		114.04	125,290		953.13	119,650
7	Spend 2005 and mortality 2002/3/4	17,625		141.22	125,290		909.96	155,196
8	Infectious diseases	1053	0.792	8.34	2050	0.047	0.76	10,928,905
9	Endocrine problems	1852	0.953	17.65	1542	0.842	12.37	1,426,410
10	Neurological problems	2790	0.616	17.19	727	0.112	0.50	34,265,082
11	Genitourinary problems	3482	0.912	31.76	294	0.051	0.14	232,226,224
12	Trauma and injuries	2892	0.358	10.35	1037	0	0.00	N/A
13	Maternity and neonates	3574	0.224	8.01	2189	0.482	2.36	3,387,363
Other six programmes summary								
14	Spend 2006 and mortality 2006/7/8	15,643		93.29	7839		16.14	5,780,723
15	Spend 2006 and mortality 2004/5/6	15,643		112.13	7923		18.17	6,172,491
16	Spend 2005 and mortality 2002/3/4	12,743		99.44	7923		16.26	6,115,621

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2006/7/8	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for YLL coverage (£)
0.984	100.14	191,407	2,207,021	1170	0.984	1189	16,383	16,121
0.992	320.88	103,683	1,361,634	3515	0.992	3543	9466	9390
0.773	262.57	83,676	324,223	1924	0.773	2489	11,593	8961
0.571	73.90	223,288	345,908	790	0.571	1,83	20,892	11,929
	761.49	119,823	4,238,786	7399		8604	12,333	10,604
			4,335,559	10,576			10,783	
			4,516,953	10,986			12,855	
1.000	0.76	10,928,905	106,552	13	1.000	13	630,798	630,798
0.634	19.52	904,344	57,672	154	0.634	243	114,416	72,539
0.136	3.69	4,660,051	66,137	15	0.136	112	1,129,960	153,675
0.172	0.80	39,942,910	10,030	2	0.172	9	20,421,090	3,512,427
0.175	0.00	N/A	30,000	0	0.175	0	N/A	N/A
8.213	0.29	27,820,413	492,600	177	0.679	261	45,158	30,662
	25.05	3,724,129	762,991	362		639	258,046	146,108
			757,531	249			449,706	
			751,009	337			295,074	

TABLE 69 Table showing cost of life and life-year estimates using expenditure data for 2006 and outcome data for 2006/7/8 (assumes average health gain for 12 other programmes) adjusted for the ICD-10 coverage of the expenditure and outcome data (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
All 10 programmes summary								
17	Spend 2006 and mortality 2006/7/8	32,911	0.561	184.53	128,640		681.24	270,881
18	Spend 2006 and mortality 2004/5/6	32,911	0.687	226.18	133,213		971.30	232,861
19	Spend 2005 and mortality 2002/3/4	30,368	0.792	240.67	133,213		926.22	259,838
Other 13 PBCs? Assume zero health gain in PBC 23 …								
20	PBC 23 spend 2006 and mortality 2006/7/8	10,585	0.739	78.22			0.00	
21	PBC 23 spend 2006 and mortality 2004/5/6	10,585	0.759	80.34			0.00	
22	PBC 23 spend 2005 and mortality 2002/3/4	8449	0.926	78.24			0.00	
… and that the gain in 10 PBCs (see row 17) applies to the remaining 12 PBCs								
23	12 PBCs spend 2006 and mortality 2006/7/8	24,400		416.20			1536.48	270,881
24	12 PBCs spend 2006 and mortality 2004/5/6	24,400		372.44			1599.42	232,861
25	12 PBCs spend 2005 and mortality 2002/3/4	25,493		324.20			1247.69	259,838
26	23 PBCs spend 2006 and mortality 2006/7/8	67,896		678.96			2217.72	306,153

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2006/7/8	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for YLL coverage (£)
	786.54	234,617	5,001,777	7760		9243	23,780	19,965
			5,093,090	10,826			20,893	
			5,267,962	11,322			21,256	
				0.00		0.00		
				0.00				
				0.00				
	1773.97	234,617		17,502		20,847	23,780	19,965
				17,826			20,893	
				15,252			21,256	
	2560.50	265,167		25,262		30,090	26,876	22,565

TABLE 69 Table showing cost of life and life-year estimates using expenditure data for 2006 and outcome data for 2006/7/8 (assumes average health gain for 12 other programmes) adjusted for the ICD-10 coverage of the expenditure and outcome data (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2006/7/8	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
27	23 PBCs spend 2006 and mortality 2004/5/6	67,896		678.96			2570.72	264,113
28	23 PBCs spend 2005 and mortality 2002/3/4	64,310		643.10			2173.90	295,827

N/A, not applicable.

Note

All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Annual mortality figures reported in cells F6 and F7, and F15 and F16 are identical because we do not have mortality data for 2002/3/4.
We have been unable to obtain a satisfactory outcome model for trauma and injuries and have assumed a zero outcome elasticity.
For expenditure in 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.
The adjustment for the coverage of the YLL data relative to the spend data uses deaths under age 75 years in England in 2008.

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2006/7/8	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for YLL coverage (£)
				28,652			23,697	
				26,575			24,200	

TABLE 70 Table showing Department of Health-funded expenditure by major bodies, 2006/7

Body	Gross spend, £B	Income, £B	Net spend, £B
PCTs	69.8	2.5	67.3
SHAs	3.8	0.0	3.8
Special Health Authorities[a]	2.8	1.3	1.5
Department of Health own costs (e.g. PSS grants, grants to LAs)	7.1	–0.4	7.5
Total Department of Health	83.5	3.4	80.1

PSS, Personal Social Services.
a This includes, for example, NICE, the NHS Business Services Authority, the Information Centre, the NHS Litigation Authority, and the National Patient Safety Agency.

TABLE 71 Table showing net PCT and other Department of Health-funded expenditure by PBC, 2006/7

PBC		Net spend, £B, 2006/7			
		(A) All PCTs	(B) Others	(C) All Department of Health	(D) Others' spend as % of PCT spend
1	Infectious diseases	1.1	0.1	1.2	13.3
2	Cancers and tumours	4.1	0.0	4.2	0.8
3	Disorders of blood	0.8	0.1	0.9	12.0
4	Endocrine, nutritional and metabolic issues	1.9	0.1	2.0	5.4
5	Mental health disorders	8.4	0.3	8.7	3.2
6	Problems of learning disability	2.4	–0.1	2.4	–2.5
7	Neurological	2.8	0.0	2.8	1.3
8	Problems of vision	1.4	0.0	1.3	–1.8
9	Problems of hearing	0.3	0.0	0.3	0.5
10	Problems of circulation	6.2	0.2	6.4	4.0
11	Problems of the respiratory system	3.3	0.1	3.3	1.6
12	Dental problems	2.6	–0.2	2.4	–7.0
13	Problems of the gastrointestinal system	3.7	0.0	3.7	–0.5
14	Problems of the skin	1.4	0.0	1.5	2.2
15	Problems of the musculoskeletal system	3.4	0.0	3.4	–0.3
16	Problems due to trauma and injuries	2.9	0.0	2.9	–0.5
17	Problems of the genitourinary system	3.5	0.1	3.6	2.1
18	Maternity and reproductive health	2.9	–0.1	2.8	–2.2
19	Conditions of neonates	0.7	0.1	0.7	10.3
20	Adverse effects and poisoning	0.7	0.0	0.7	–0.8
21	Healthy individuals	1.4	0.0	1.4	0.8
22	Social care needs	1.5	0.0	1.5	0.9
23	Other areas of spend/conditions	10.6	11.2	21.8	106.1
	All categories	67.9	12.0	79.9	17.7

Note
The figures in *Tables 70* and *71* draw on various sources (e.g. Department of Health resource accounts and PB returns) and may (a) disagree slightly and (b) create some unusual results (e.g. the aggregate PCT figure for dental problems exceeds the all England level[34]).

This is because all of the additional non-PCT expenditure is allocated to PBC 23 and the assumption is that all expenditure in this category offers no health gain.

We have no information on how any Departmental budgetary shock is likely to be split between PCT and non-PCTs budgets. Our cost of a life-year estimates implicitly assume that the non-PCT budget is wholly unresponsive to any budgetary shock. This is clearly a possibility. Alternatively, one might assume that the non-PCT budget is as responsive to a Departmental budgetary shock as is the PCT budget. If this was the case then it would add 17.7% to our cost of a life-year estimate for 2006/7. However, in the absence of any information about the responsiveness of the non-PCT budget, it is difficult to come to any firm conclusion about the impact of non-PCT expenditure on our cost of a life-year estimates. We therefore persevere with the assumption that the non-PCT budget is wholly unresponsive to Departmental budgetary shocks.

Application of method to other non-mortality-based outcome indicators

Not all health-care expenditure will be directed towards the reduction of mortality but it is relatively easy to envisage how our methods might be applied to other, non-mortality-based, outcome indicators. To illustrate how our approach might be applied to other such indicators we note that PROMs (health gain) data for various operations is available from the HES online website. For each PCT this data set reports the average health gain for those survey respondents who have had a specific operation (e.g. for hip replacement, for knee replacement, for varicose veins, and for groin hernia) over the survey period.

As a starting point, and to illustrate the principles involved, we focus on hip and knee replacements. As our outcome indicator for these procedures, we calculate:

$$[(\text{average health gain per hip operation} \times \text{number of hip operations}) + (\text{average health gain per knee operation} \times \text{number of knee operations})]/\text{total PCT population},$$

for each PCT (this ignores age standardisation). This health gain measure is broadly comparable with our usual mortality measure, which is a 'YLL' rate per 10,000 of population (again, ignoring age standardisation).

Ideally the expenditure, number of operations and PROMs data should all relate to the same time period, but here the PROMs data covers operations undertaken between April 2009 and October 2010 yet the expenditure and number of operations data relate to 2006/7. Implicitly, we are assuming that the average gain per operation in 2006/7 is the same as over the PROMs survey period (although this is not particularly important as we are only illustrating principles here).

Unfortunately, the Department of Health does not report the number of patients undergoing an eligible operation by commissioner (PCT) so we use the HES data set for 2006/7 to obtain this information. Eligible hip and knee operations are defined in annex 1 of the *Guide to PROMs methodology* (on the HES website)[151] and we use these definitions (of eligible operation codes) to obtain a count of eligible hip and knee FCEs by PCT for 2006/7.

With data for both the average health gain per operation and the number of operations, we are now in a position to calculate 'the health gain per head of population' for hip and knee replacements as defined above. We can then use this as an outcome indicator for expenditure in the 'problems of the musculoskeletal system' programme (i.e. PBC 15) because the vast majority of hip and knee replacements are for osteoarthritis and this diagnosis is included in PBC 15.

Table 72 reports the estimated outcome equation for PBC 15 using the PROMs-based outcome indicator. The result is intuitively plausible. More expenditure boosts the health gain but, for a given spend, more need reduces the gain. Of course we should remember that the health gain data relates to operations undertaken between April 2009 and October 2010 yet the expenditure and number of operations data (FCEs) relate to 2006/7. However, one might assume that the gain associated with each operation in 2009/10 is the same as the gain associated with each operation in 2006/7.

The diagnostic statistics suggest that expenditure is endogenous and that the instruments are valid. They also suggest that the instruments are relevant and there is no evidence that the instruments are weak. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

This brief example illustrates the principles involved in extending our modelling approach beyond those programmes with a mortality indicator.

Comparing outcome models for 'high' spending and 'low' spending primary care trusts

As we have already noted, not all PCTs spend the same amount in each programme of care. Even after allowing for differences in local circumstances (such as input prices and need), some PCTs spend more than others, and it is this variation in expenditure that facilitates the estimation of our outcome and expenditure models.

TABLE 72 Table showing outcome model for PBC 15, problems of the musculoskeletal system 2006/7

Regressors	Coefficient (standard error)
Expenditure per person in PBC 15	1.9068***
	(0.4289)
Need CARAN per person	–1.6807***
	(0.4533)
Constant	–6.3486***
	(1.794)
Number of PCTs	143
Diagnostic test statistics	
Endogeneity test statistic	24.677
Endogeneity *p*-value	0.0000
Hansen-Sargan test statistic	1.136
Hansen-Sargan *p*-value	0.2865
Kleibergen–Paap LM test statistic	14.702
Kleibergen–Paap *p*-value	0.0006
Kleibergen–Paap *F*-statistic	10.367
Pesaran–Taylor reset statistic	0.03
Pesaran–Taylor *p*-value	0.8588

*** $p < 0.01$.
Robust standard errors in brackets.
The dependent variable is the health gain per head of population associated with eligible hip and knee operations undertaken during 2006/7.
There are only 143 observations and not the usual 152 because, for the other nine PCTs, there are fewer than 30 completed PROMs questionnaires on which to compute the average health gain and, as a result of such a low number of respondents, these PCTs have been dropped from the sample.
The first-stage regression includes the IMD2007 (coefficient = –0.439, standard error = 0.144) and the proportion of residents providing unpaid care (coefficient = 0.219, standard error = 0.367).

Figure 15 illustrates the familiar health gain production function; as expenditure increases so too does health output but it increases at a diminishing rate. If all PCTs face the same production function (having controlled for input prices and need), and all PCTs are wholly efficient, then we would expect those PCTs that spend more (e.g. at point B) to experience a lower outcome elasticity than those that spend less (e.g. at point A), simply because they are further along the production function and are experiencing greater diminishing marginal returns.

To test this hypothesis we used the expenditure model for each of the big four programmes to divide the 152 PCTs into two groups: those whose predicted spend is greater than the average predicted spend in that programme (ceteris paribus), and those whose predicted spend is smaller than the average predicted spend (ceteris paribus). We then re-estimated our outcome model for each of these two groups of PCTs and the results of this re-estimation are shown in *Table 73*.[ad]

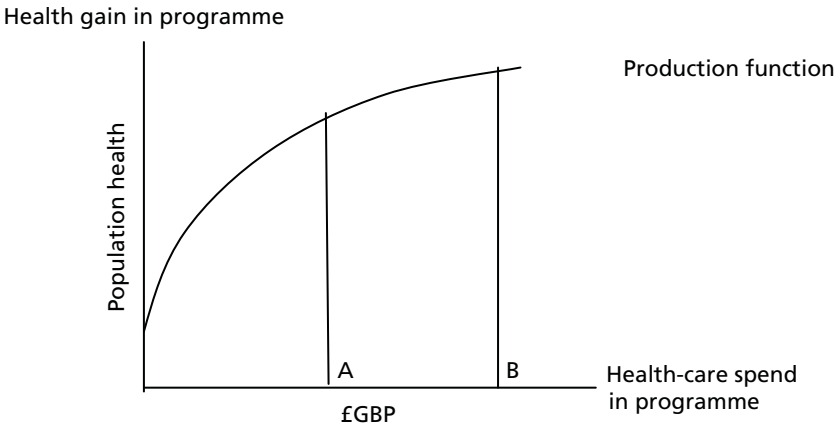


FIGURE 15 Graph showing health gain production function.

TABLE 73 Table showing re-estimating the 2006/7 outcome model for 'high' spending and 'low' spending PCTs

IV regression result	All PCTs	'High spend' PCTs	'Low spend' PCTs
Cancer outcome equation			
1 Constant	6.500***	7.132***	5.352***
2 Need for health care	0.995***	1.265***	0.848***
3 Need for health care squared	1.162***	0.588	0.842
4 Cancer expenditure per person	–0.342***	–0.488***	–0.074
Number of observations	152	76	76
Endogeneity test statistic	13.695***	7.165***	0.501
Instrument validity: Hansen J statistic	0.685	0.734	1.587
Instrument relevance: Kleibergen–Paap LM statistic	17.847***	7.102**	13.617***
Weak instrument: Kleibergen–Paap *F*-statistic	13.279	6.722	7.436
Reset test	0.01	0.68	1.95
Circulatory disease outcome equation			
1 Constant	11.413***	11.254***	9.356***
2 Need for health care	2.859***	2.741***	2.636***

continued

TABLE 73 Table showing re-estimating the 2006/7 outcome model for 'high' spending and 'low' spending PCTs (*continued*)

IV regression result	All PCTs	'High spend' PCTs	'Low spend' PCTs
3 Circulatory expenditure per person	−1.434***	−1.403***	−0.995***
Number of observations	152	76	76
Endogeneity test statistic	42.548***	9.424***	20.489***
Instrument validity: Hansen J statistic	0.949	4.782	0.366
Instrument relevance: Kleibergen–Paap LM statistic	32.372***	12.658**	15.123***
Weak instrument: Kleibergen–Paap *F*-statistic	17.143	6.275	12.421
Reset test	0.14	0	1.29
Respiratory problems outcome equation			
1 Constant	17.023***	22.617**	11.695***
2 Need for health care	2.683**	2.512	3.095**
3 Need for health care squared	3.08	5.537	8.097***
4 Permanently sick	1.031**	1.401	0.844
5 Respiratory expenditure per person	−2.622***	−3.697*	−1.461*
Number of observations	152	76	76
Endogeneity test statistic	20.860***	10.254***	5.380**
Instrument validity: Hansen J statistic	N/A	N/A	N/A
Instrument relevance: Kleibergen–Paap LM statistic	9.091***	3.591	5.108**
Weak instrument: Kleibergen–Paap *F*-statistic	11.025	4.568	6.227
Reset test	0	0.08	0.21
Gastrointestinal outcome equation			
1 Constant	9.718***	9.306***	6.675***
2 Need for health care	4.159***	5.156***	3.236***
3 Gastrointestinal spend per person	−1.536***	−1.471***	−0.819
Number of observations	152	76	76
Endogeneity test statistic	16.373***	7.781***	3.700*
Instrument validity: Hansen J statistic	2.761	1.529	3.824*
Instrument relevance: Kleibergen–Paap LM statistic	14.865***	10.094***	7.956**
Weak instrument: Kleibergen–Paap *F*-statistic	11.629	10.607	7.985
Reset test	1.67	0.15	0.56

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; N/A, not applicable.

In *Table 73* the first column of the IV regression results presents the outcome model for all PCTs; the second column reports the results for the 'high spend' PCTs; and the third column reports the results for the 'low spend' PCTs. For all four programmes, the coefficient on the expenditure variable is larger (in an absolute sense) for the 'high spend' PCTs than for the 'low spend' PCTs. This result contradicts our hypothesis that 'high spenders' will have a lower elasticity than 'low spenders'.

However, if we drop the assumption that all PCTs are equally efficient – so that that some lie within the frontier defined by the production function – then it is clearly possible for 'high' spending PCTs to experience a larger outcome elasticity than a 'low' spending one. In addition, it is rather difficult to defend the assumption that all PCTs are equally efficient.

We can use the outcome elasticities reported in *Table 73* to calculate the cost of a life-year for 'high' and 'low' spenders in each of the big four programmes. These calculations are shown in *Table 74*.[ae] As is to be anticipated, they reveal that the cost of a life-year is much smaller in 'high spend' PCTs than it is in 'low spend' PCTs. For example, the cost of a life-year in the cancer programme is £16,383 across all PCTs, but for 'high spenders' it is much less than this (£11,350) and for 'low spenders' it is much greater than this (£76,620). Presumably 'high spending' PCTs are high spenders because the cost of a life-year is relatively low and additional health gains in a particular programme can be had relatively cheaply. Similarly, 'low spending' PCTs are low spenders because the cost of a life-year is relatively high and additional health gains are relatively expensive.

Comparing outcome models for over target and under target primary care trusts

The Department of Health has a well-developed resource allocation formula that determines the size of each PCTs 'target' budget given local conditions (such as population size and the need for health care). Every few years an improved resource allocation formula is developed and this generates a new 'target' budget for each PCT. The new target might be quite different from the old target and the immediate implementation of the new formula might lead to a large change in the budget for some PCTs. To avoid the difficulties that sudden large budgetary changes might bring, actual annual financial allocations are gradually moved towards the latest target budget. This means that in any year some PCTs receive an actual allocation which is greater than their target allocation, and that others receive an actual allocation which is less than their target allocation.

To examine whether or not being over or under the target allocation has any impact on the results, we split the 152 PCTs into two groups: those that received a budget over their target allocation in 2006/7 and those that received a budget under their target allocation in 2006/7. The outcome elasticities from the estimation of these models are shown in column (E) of *Table 75*, and these elasticities are used to calculate the cost of a life-year for each of these two groups of PCTs for each of the big four programmes [see column (I) of *Table 75*].

The results are consistent for each programme: PCTs whose budget is beyond their target allocation record a smaller outcome elasticity and a larger cost of a life-year than PCTs whose budget is less than their target allocation. For example, in the cancer programme and across all PCTs the outcome elasticity is –0.342 and the cost of a life-year is £16,383 (unadjusted for the ICD-10 coverage of the mortality data). For PCTs with a budget that exceeds their target allocation, the outcome elasticity is smaller (–0.179) and the cost of a life-year is larger (£32,365) than for all PCTs combined. However, for PCTs with a budget that falls short of their target allocation, the outcome elasticity is larger (–0.476) and the cost of a life-year is smaller (£11,502) than for all PCTs combined.

One explanation for this result is that PCTs whose budget is beyond their target allocation are under less financial pressure than other PCTs, and that one consequence of this is that there is less pressure on them to behave in the most efficient manner possible. There is some evidence in the literature to support the

TABLE 74 Table showing calculation of the cost of a life-year for the big four programmes in 2006/7 by type of PCT: 'high spenders' and 'low spenders'

Scenario	(A) PBC description	(B) Type of PCT	(C) Spend (£M) financial year 2006/7	(D) 1% of spend (£M) financial year 2006/7	(E) Outcome elasticity (without negative sign)	(F) Total life-years lost, < 75 years, 2006/7/8	(G) Annual average life-years lost (= F/3)	(H) Change in annual life-years lost associated with 1% increase in spend (= E × G)/100	(I) Cost (£) per YLG (= D/H) unadjusted for ICD-10 coverage
Split PCTs according to whether they are 'high spenders' (n = 76) or 'low spenders' (n = 76)									
1	Cancers	All	4122	41.22	0.342	2,207,021	735,674	2516	16,383
2	Cancers	High spend	2080	20.80	0.488	1,126,580	375,527	1833	11,350
3	Cancers	Low spend	2042	20.42	0.074	1,080,442	360,147	267	76,620
4	Circulatory problems	All	6161	61.61	1.434	1,361,634	453,878	6509	9466
5	Circulatory problems	High spend	3148	31.48	1.403	695,890	231,963	3254	9673
6	Circulatory problems	Low spend	3012	30.12	0.995	665,744	221,915	2208	13,641
7	Respiratory problems	All	3285	32.85	2.622	324,223	108,074	2834	11,593
8	Respiratory problems	High spend	1645	16.45	3.697	174,639	58,213	2152	7644
9	Respiratory problems	Low spend	1640	16.4	1.461	149,584	49,861	728	22,513
10	Gastrointestinal problems	All	37.00	37.00	1.536	345,908	115,303	1771	20,892
11	Gastrointestinal problems	High spend	1868	18.68	1.471	190,231	63,410	933	20,026
12	Gastrointestinal problems	Low spend	1832	18.32	0.819	155,676	51,892	425	43,106

Note
'High spending' PCTs are those whose predicted spend per person is greater than the average predicted spend per person (ceteris paribus), and 'low spending' PCTs are those whose predicted spend per person is less than the average predicted spend per person (ceteris paribus).

TABLE 75 Table showing calculation of the cost of a life-year for the big four programmes by type of PCT: over target and under target allocations

Scenario	(A) PBC description	(B) Type of PCT	(C) Spend (£M) financial year 2006/7	(D) 1% of spend (£M) financial year 2006/7	(E) Outcome elasticity (without negative sign)	(F) Total life-years lost, < 75 years, 2006/7/8	(G) Annual average life-years lost (= F/3)	(H) Change in annual life-years lost associated with 1% increase in spend (= E × G)/100	(I) Cost (£) per YLG (= D/H)
Split PCTs according to whether they are over target allocation (n = 67) or under target allocation (n = 85)									
1	Cancers	All	4122	41.22	0.342	2,207,021	735,674	2516	16,383
2	Cancers	Over target	1733	17.33	0.179	897,403	299,134	535	32,365
3	Cancers	Under target	2390	23.90	0.476	1,309,618	436,539	2078	11,502
4	Circulatory problems	All	6161	61.61	1.434	1,361,634	453,878	6509	9466
5	Circulatory problems	Over target	2587	25.87	1.115	544,326	181,442	2023	12,787
6	Circulatory problems	Under target	3574	35.74	1.947	817,308	272,436	5304	6738
7	Respiratory problems	All	3285	32.85	2.622	324,223	108,074	2834	11,593
8	Respiratory problems	Over target	1357	13.57	2.637	127,810	42,603	1123	12,079
9	Respiratory problems	Under target	1928	19.28	2.674	196,413	65,471	1751	11,013
10	Gastrointestinal problems	All	3700	37.00	1.536	345,908	115,303	1771	20,892
11	Gastrointestinal problems	Over target	1566	15.66	0.569	142,281	47,427	270	58,030
12	Gastrointestinal problems	Under target	2134	21.34	1.869	203,626	67,875	1269	16,822

Note that for those over target, the average amount (percentage) is £13.415M (3.6%); for those under target, the average amount (percentage) is £10.575M (2.6%).

hypothesis that the degree of PCT inefficiency is positively related to the amount by which a PCTs is over its target allocation.[61]

If we also re-estimate the expenditure models for both groups of PCTs we can calculate the cost of a life-year for the big four programmes combined. The relevant expenditure elasticities are shown in column (D) of *Table 76*. These expenditure elasticities are far larger for under target PCTs than they are for over target PCTs. One reason for this might be that the big four programmes are priority ('hard') programmes. Over target PCTs are able to devote sufficient resources to the big four programmes so that any additional budget is directed towards other ('softer') programmes which are less well funded than the priority programmes. In contrast, under target PCTs are struggling to devote sufficient resources to the priority programmes so that, when further funding does become available, this is directed towards the priority programmes.

These expenditure and outcome elasticities in *Table 76* can be used to calculate the cost of a life-year for the big four programmes combined (adjusted for the ICD-10 coverage of the mortality data). This cost is:

- £10,604 for all PCTs combined
- £14,083 for PCTs whose budget is beyond its target allocation
- £8441 for PCTs whose budget falls short of its target allocation.

Again, the cost of a life-year is much smaller for PCTs whose budget falls short of its target allocation.

The correlation between the outcome and expenditure elasticities

To investigate the correlation between the outcome and expenditure elasticities for any given programme, a random sample (with replacement) of 152 PCTs was drawn from the population of 152 PCTs. In this random drawing, some of the original observations will appear once, some more than once, and some not at all. Using this resampled data set, outcome and expenditure models for the selected programme were estimated (as per *Table 65*) and the outcome and expenditure elasticities saved. This step was repeated 500 times and the correlation coefficient for the outcome and expenditure elasticities was calculated. *Table 77* shows these correlation coefficients for each of the big four programmes.

Summary and conclusion

In this section we have undertaken several tasks. First, we have identified and resolved several estimation issues relating to the appropriate measure of need, the appropriate price index to be used to adjust PCT expenditure for local variations in input prices, and the fact that PCTs vary in size.

Second, we have derived plausible outcome and expenditure models for 10 care programmes using expenditure data for 2006/7 and mortality data for 2004/5/6. The cost of a life-year across these 10 programmes is £20,893 (it was £21,256 using expenditure data for 2005/6).

Third, we have re-estimated the outcome and expenditure models using the same expenditure data but replacing the mortality data for 2004/5/6 with data for 2006/7/8. The advantage of this is that it assumes that the health benefits associated with expenditure occur either in the same period as the expenditure or in the next two periods. This is an improvement on past practice where data constraints forced researchers to relate expenditure to the current and two previous periods. This re-estimation increased the cost of a life-year across all 10 programmes by 14%, from £20,893 to £23,780.

Fourth, we have adjusted the cost of a life-year calculations for the mismatch in the ICD-10 coverage of the expenditure and mortality data. This reduces the cost of a life-year for 2006/7 for those 10 PBCs with a mortality indicator from £23,780 to £19,965 (a decrease of 16%).

Fifth, we have noted that our cost of a life-year estimates are based on the assumption that any Departmental budgetary change falls entirely on PCTs. Although PCTs account for most of the Department of Health's budget, non-PCTs still accounted for 15% of the budget in 2006/7. As we have no information on how any budgetary change would be split between PCTs and non-PCTs, our estimates implicitly assume that any Departmental budgetary change falls entirely on PCTs. If, on the other hand, the non-PCT budget is responsive to changes in the Department's budget then our cost of a life-year estimates will be slightly too low [e.g. if the non-PCT budget is as responsive as the PCT budget, then our cost of a life-year estimate for 2006/7 will be increased by 17.7% (that is, from £22,565 to £26,553)].

We have also illustrated how our modelling framework can be applied to other non-mortality-based outcome indicators, and the cost of a life-year estimates that are obtained if PCTs are split into different groups (e.g. those that are under and those that are over their target budget allocations). In the next section we examine the impact of relaxing the instrument validity restriction on our results.

The sensitivity of the outcome elasticity to the validity of the instrument exclusion restrictions

Introduction

One of the crucial elements in the calculation of the cost of a life-year for any programme of care is the coefficient on the expenditure variable in the outcome equation. This coefficient indicates the amount by which mortality changes following a (small) change in expenditure in that care programme. It is to be expected that this coefficient will have a negative sign so that as expenditure increases, for example, mortality will decline. If this coefficient is small (in an absolute sense) then it implies that any change in expenditure will have little effect on mortality and so the cost of a life-year will be relatively large (ceteris paribus). Alternatively, if this coefficient is large (in an absolute sense) then any change in expenditure will have a large effect on mortality and so the cost of a life-year will be relatively small (ceteris paribus). For this reason it is important that we correctly identify the magnitude of this 'treatment parameter'.

Our basic outcome model for each programme of care is:

$$y = \alpha + \beta 1x + \beta 2n + \varepsilon, \tag{15}$$

where y is mortality, x is expenditure, and n is a measure of the need for health care (with all variables relating to a particular programme of care). We are particularly interested in the size of the coefficient on expenditure ($\beta 1$). We do not use OLS to estimate this outcome model because expenditure (x) is endogenous and, in the presence of an endogenous regressor, OLS will provide both a biased and an inconsistent estimator of $\beta 1$. Instead, we use IV techniques. Unlike OLS, IV will provide a consistent estimator of $\beta 1$ and, although in finite samples the IV estimator will be biased, the belief is that (providing certain assumptions are met) this bias will be less than that associated with OLS.

Instrumental variable estimation involves finding variables (instruments) that are good predictors of expenditure (x), but which are appropriately excluded from the equation of interest (that is, *Equation 15*). The assumption is that the instruments impact on mortality (y) through their impact on expenditure (x) only, and that they do not have a direct effect on mortality (y). If, on the other hand, an instrument reflects unobserved factors that affect both expenditure and mortality directly, the use of this instrument will lead to a biased and inconsistent estimate of the coefficient on expenditure. Such an instrument is said to be 'invalid' because it belongs in the equation of interest in its own right.

TABLE 76 Table showing cost of life and life-year estimates using spend data for 2006 and outcome data for 2006/7/8 for the big four PBCs for (i) all PCTs; (ii) PCTs that are over target; and (iii) PCTs that are under target

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2006/7	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality < 75 years, 2006/7/8	(G) Coverage of mortality data relative to spend data	(H) Outcome elasticity (without negative sign)
All PCTs together							
1	Cancer	4122	0.465	19.17	61,961	0.984	0.342
2	Circulatory problems	6161	0.540	33.27	41,106	0.992	1.434
3	Respiratory problems	3285	0.679	22.31	11,574	0.773	2.622
4	Gastrointestinal problems	3700	0.446	16.50	6160	0.571	1.536
Big four programmes summary							
5	Spend 2006 and mortality 2006/7/8	17,268		91.24			
For over target PCTs only (n = 67)							
6	Cancer	1733	0.193	3.34	24,918	0.984	0.179
7	Circulatory problems	2587	0.150	3.88	16,346	0.992	1.115
8	Respiratory problems	1357	0.326	4.42	4588	0.773	2.637
9	Gastrointestinal problems	1566	0.090	1.41	2525	0.571	0.569
Big four programmes summary							
10	Spend 2006 and mortality 2006/7/8	7243		13.06			
For under target PCTs only (n = 85)							
11	Cancer	2390	0.785	18.76	37,043	0.984	0.476
12	Circulatory problems	3574	0.748	26.73	24,760	0.992	1.947
13	Respiratory problems	1982	1.035	20.51	6986	0.773	2.674
14	Gastrointestinal problems	2134	0.592	12.63	3602	0.571	1.869
Big four programmes summary							
15	Spend 2006 and mortality 2006/7/8	10,080		78.64			

Note
All 23 programmes spend: 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2006/7 0.01; 2005/6 0.01.
Change in budget: 2006/7 £678.96; 2005/6 £643.10.
Note that the adjustment for the coverage of the YLL data relative to the spend data uses deaths under age 75 years in England in 2008

(I) (= 0.01 × D × F × H/G) change in annual mortality, adjusted for coverage	(J) (= E/I) cost per life gained adjusted for coverage (£)	(K) Total life-years lost, < 75 years, 2006/7/8	(L) (= 0.01 × D × H × K/3) change in annual life-years lost	(M) Coverage of mortality data relative to spend data	(N) (= L/M) change in annual life-years lost, adjusted for coverage	(O) (= E/L) cost per YLG (£)	(P) (= E/N) cost per YLG adjusted for YLL coverage (£)
100.14	191,407	2,207,021	1170	0.984	1189	16,383	16,121
320.88	103,683	1,361,634	3515	1.000	3543	9466	9390
266.57	83,676	324,223	1924	0.773	2489	11,593	8961
73.90	223,228	345,908	790	0.650	1383	20,892	11,929
761.49	119,823		7399		8604	12,333	10,604
8.75	382,320	897,403	103	0.984	105	32,365	31,847
27.56	140,806	544,326	303	1.000	303	12,787	12,685
51.02	86,701	127,810	366	0.773	474	12,079	9337
2.26	622,378	142,281	24	0.650	43	58,030	33,135
89.60	145,748		797		927	16,378	14,083
140.67	133,377	1,309,618	1631	0.984	1658	11,502	11,318
363.50	73,544	817,308	3968	1.000	4000	6738	6684
250.12	82,015	196,413	1812	0.773	2344	11,321	8751
69.80	181,000	203,626	751	0.650	1315	16,822	9605
824.09	95,429		8162		9317	9635	8441

TABLE 77 Table showing correlation coefficient for the outcome and expenditure elasticities

Programme of care	Correlation coefficient between the outcome and expenditure elasticities
Cancers and tumours	0.1542
Circulatory disease	0.1968
Respiratory problems	0.0368
Gastrointestinal problems	0.0611

Note
The estimated elasticities are from unweighted IV regressions because there is no weight option with the bootstrap command in Stata. However, weighting makes little difference to our IV results. For example, in the cancer outcome model the coefficient on spend is –0.342 with weighting applied but it is –0.299 without any weighting applied. For the cancer spend model the coefficient on budget is 0.465 with weighting but 0.520 without weighting.

In our outcome models we typically employ two instruments (call these $z1$ and $z2$) for expenditure. IV assumes that these instruments do not belong in the outcome (see *Equation 15*). In other words, IV assumes that the coefficients $\gamma 1$ and $\gamma 2$ in the outcome model:

$$y = \alpha + \beta 1x + \beta 2n + \gamma 1z1 + \gamma 2z2\varepsilon, \tag{16}$$

are identically zero. Such exclusion restrictions can be debatable and researchers who employ IV techniques often devote considerable effort towards convincing the reader that their assumed exclusion restrictions are a good approximation.[88,89] These efforts usually take two forms: first, researchers often offer a strong theoretical economic argument why their instruments do not belong in the equation of interest; and, second, statistical tests for the validity of the exclusion restrictions (Sargan 2SLS, Hansen J-test GMM) are routinely reported as part of the results for any study that employs IV techniques.

It is difficult for us to identify clear theoretical reasons why our instruments (such as the proportion of lone pensioner households, the provision of unpaid care and an index of multiple deprivation) do not belong in the equation of interest (that is, that they will not *directly* affect mortality). Of necessity, therefore, we must be guided by the available statistical tests for the validity of the exclusion restrictions. However, although our outcome models 'pass' the relevant statistical test, some commentators have argued that the Sargan/Hansen test may have weak power and may fail to reject the null hypothesis of instrument validity even when an exclusion restriction is not valid. Given our reliance on this test, it is important that we examine the circumstances in which this test may have weak power.

The Hansen–Sargan test of overidentifying restrictions: when will it have low power?

As we have one endogenous variable (expenditure) in our outcome model and more than one instrument available for health-care expenditure, our estimating equation is said to be 'overidentified'. With more instruments than endogenous regressors, there is more than one way of using the instruments to estimate the parameter $\beta 1$ on the endogenous variable. The Hansen–Sargan J test of overidentifying restrictions calculates whether different instruments or different combinations of instruments generate significantly different values for the coefficient ($\beta 1$) on the endogenous variable in the equation of interest. If significant differences are detected then the test will reject the null hypothesis that all instruments are jointly valid. Of course, the test does not reveal *which* instrument(s) is(are) invalid; instead, the test uses the fact that different instruments (or combinations thereof) generate different estimates of $\beta 1$ to infer that something is wrong with the set of instruments. Even if all of the instruments are invalid in the sense that they are all correlated with the error term in the equation of interest (and thus belong in the outcome equation as regressors), the test can detect this failure if the induced biases in the estimates of $\beta 1$ differ across instruments. This 'vector-of-contrasts' interpretation of the Hansen–Sargan test makes it clear when the J test will lack power to reject the null hypothesis when it is false. The J statistic will be small when the null

hypothesis of valid instruments is correct; but it will also be small if the biases induced in $\widehat{\beta 1}$ by invalid instruments all coincide (i.e. the instruments all identify the *same* wrong parameter).[150]

Most of our estimated models involve the use of two instruments. Kovandic *et al.*[150] point that when there are only two instruments:

> *. . . the J test statistic is numerically identical to a Hausman test statistic that contrasts the estimator using both instruments with an estimator using just one instrument. The intuition [behind this result] is . . . straightforward: a Hausman test will reject the null hypothesis that the two estimators being contrasted are both consistent so long as the estimators converge to different values. It is not a requirement for one of the two estimators to be consistent for the Hausman test (and therefore the J test) to have power to reject the null.*

One implication of this observation is that misspecification, in the conditional mean of the model, need not necessarily cause the Hansen–Sargan test to fail.

Kovandic *et al.* point out that these arguments suggest:

> *'. . . that the more unrelated the instruments are to each other, the more credible is a failure to reject the null that the instruments are exogenous, since a failure to reject would require that two unrelated instruments generate the same asymptotic bias in* $\widehat{\beta 1}$
>
> *p. 19*[150]

Schaffer argues that:

> *[d]ifferent sets of instruments are likely to have more or less power depending on where they come from. If all the instruments are minor variations on the same variable – e.g. they are the same variable but lagged a few different periods – then they are all likely to identify the same psuedo-parameter. The critique of low power is going to be fairly convincing here.*
>
> *Professor Mark Schaffer, Heriot-Watt University, 2011, personal communication*

On the other hand, if the instruments are very different and, even better, there are ex ante reasons for thinking that if they are invalid, they are invalid in 'different ways', the J test will have more power. For example, suppose two instruments are available and it is thought that, if one is invalid, it will bias the estimated parameter upwards but, if the other instrument is invalid, it will bias the estimated parameter downwards. If the Hansen–Sargan J test fails to reject in this setting, it is a convincing result (Professor Mark Schaffer, personal communication).

In this study we typically use any two from three available instruments when estimating our outcome equations. These three instruments are:

(a) the proportion of households that are lone pensioner households (from the 2001 Census[80])
(b) the proportion of residents providing more than 1 hour of unpaid care per week (from the 2001 Census[80]); and
(c) the IMD2007.

For the Hansen–Sargan J test to have low power the use of any two of these instruments should generate the *same* asymptotic bias in $\widehat{\beta 1}$. However, it is far from obvious that this will be the case, particularly given that our outcome equation already includes a measure of the need for health care.

Nevertheless, we must admit that it is possible that our instruments are correlated with both expenditure and some unobserved factor which is directly influencing the mortality rate, and that the induced bias in

$\widehat{\beta 1}$ is the same for both instruments. In the next section we therefore examine the sensitivity of the estimated outcome elasticity to the validity of the exclusion restrictions.

In summary:

- The Hansen–Sargan J test of overidentifying restrictions calculates whether different instruments or different combinations of instruments generate significantly different values for the coefficient (β1) on the endogenous variable in the equation of interest. If significant differences are detected then the test will reject the null hypothesis that all instruments are jointly valid.
- The J test uses the fact that different instruments (or combinations thereof) generate different estimates of β1 to infer that something is wrong with the chosen set of instruments.
- Even if all of the instruments are invalid in the sense that they are all correlated with the error term in the equation of interest, the test can detect this failure if the induced biases in the estimates of β1 differ across instruments.
- This 'vector-of-contrasts' interpretation of the Hansen–Sargan test also makes it clear when the J test will lack power to reject the null hypothesis when it is false. The J statistic will be small when the null hypothesis of valid instruments is correct; but it will also be small if the biases induced in $\widehat{\beta 1}$ by invalid instruments all coincide (i.e. the instruments all identify the *same* wrong parameter).
- Most of our outcome models use two from the following three instruments: lone pensioners, multiple deprivation and unpaid carers. Thus, our Hansen–Sargan test statistics are likely to have low power if our selected pair of instruments are both inducing the same bias in $\widehat{\beta 1}$. It is far from obvious that these instruments will induce the same bias in the coefficient on expenditure.
- However, in case our instruments are imparting the same bias to $\widehat{\beta 1}$, the next section examines the sensitivity of the estimated outcome elasticity to the validity of the exclusion restrictions.

The value selection problem

Given that the Hansen–Sargan J test might be unable to detect the presence of invalid instruments in some (rather restrictive) circumstances, several studies have suggested that researchers using IV techniques should subject the estimated coefficient on the endogenous variable to a sensitivity analysis (e.g. Conley *et al.*;[88] Small[89]). Recall that IV estimation involves the assumption that the instruments do not belong in the equation of interest (i.e. in the outcome equation). In other words, the assumption is that the coefficients $\gamma 1$ and $\gamma 2$ on the instruments $z1$ and $z2$ in the outcome model:

$$y = \alpha + \beta 1x + \beta 2n + \gamma 1z1 + \gamma 2z2 + \varepsilon, \tag{17}$$

are identically zero (where y is mortality, x is expenditure, and n is a measure of the need for health care). One suggestion is that investigators should relax the assumption that $\gamma 1$ and $\gamma 2$ are identically zero and examine the impact of this relaxation on the estimated value for $\beta 1$. This proposal, however, raises the issue of which non-zero values should be imposed on $\gamma 1$ and $\gamma 2$.

Proponents of this approach suggest that prior information about the extent of deviations from the exact exclusion restriction might be drawn from other research studies or from subject matter experts.[88,89] In the present context, however, we have no prior beliefs about the likely values for, or even the signs on, $\gamma 1$ and $\gamma 2$.

As a starting point we re-estimated the outcome model for the 2006/7 cancer programme 420 times, assuming a uniform distribution between −1 and 1 for both $\gamma 1$ and $\gamma 2$.[af,ag] *Table 78* shows the estimated coefficients on expenditure ($\widehat{\beta 1}$) in our cancer outcome equation associated with the various pairs of values imposed on $\gamma 1$ and $\gamma 2$. The coefficients in *Table 78* indicate that the outcome elasticity is rather sensitive to the precise values assigned to $\gamma 1$ and $\gamma 2$. However, in the absence of any guidance from other research studies or from subject matter experts, we require a method that will identify a plausible range of values for both $\gamma 1$ and $\gamma 2$, and which we can use as the basis for our sensitivity analysis.

The identification of values to be imposed on the coefficients on the excluded instruments

Our outcome equations typically involve two instruments and one endogenous regressor. With this structure we can re-estimate our outcome model twice, each time including one of the previously excluded instruments to the equation of interest. In particular, we can estimate:

$$y = \alpha + \beta 1x + \beta 2n + \gamma 1z1 + \varepsilon, \tag{18}$$

and then

$$y = \alpha + \beta 1x + \beta 2n + \gamma 2z2 + \varepsilon, \tag{19}$$

with the same set of (included and excluded) instruments (n, $z1$, and $z2$) being used to instrument $\times 1$ in both cases. This provides us with coefficient and variance estimates for $\gamma 1$ and $\gamma 2$ and we can sample from these point estimates and their distributions to examine the impact of different (non-zero) values for $\gamma 1$ and $\gamma 2$ on the outcome elasticity ($\widehat{\beta 1}$).

The sampling procedure is straightforward. We sample from these estimates and their distributions by drawing two random numbers from a standard normal distribution and we form the product of these numbers and the standard errors associated with our estimates of $\gamma 1$ and $\gamma 2$. Our sampled pair of values of $\gamma 1$ and $\gamma 2$ (call these sampled values $\tilde{\gamma}_1$ and $\tilde{\gamma}_2$) are then the sum of these products and the respective coefficient estimates of $\gamma 1$ and $\gamma 2$. *Table 79* shows the relevant coefficient and variance estimates for $\gamma 1$ and $\gamma 2$ that are used as part of this sampling procedure.

The estimation of *Equations 18* and *19* does not generate estimates of $\gamma 1$ and $\gamma 2$ as part of the same model and so the sampling procedure outlined above implicitly assumes a zero covariance between these estimates. If we want to incorporate a covariance term into the sampling procedure this must be obtained from elsewhere. In the absence of an obviously better approach, we obtain a covariance term from the OLS estimation of our outcome model with the previously excluded instruments both included in the regression equation. Thus we estimate:

$$y = \alpha + \beta 1x + \beta 2n + \gamma 1z1 + \gamma 2z2 \ + \varepsilon, \tag{20}$$

where y, x, n, $z1$ and $z2$ have their usual meaning, and where $\beta 1$ is constrained to be equal to its value from the IV estimation of *Equation 15*. The value for the covariance term between the estimates of $\gamma 1$ and $\gamma 2$ for each of the big four programmes is shown in the final column of *Table 79*.

The sampling procedure from our estimates of $\gamma 1$ and $\gamma 2$ with a non-zero covariance is essentially the same as that outlined above but it incorporates the presence of a covariance term for the estimates of $\gamma 1$ and $\gamma 2$. We can illustrate this procedure using data from the cancer outcome model. First, we form the implied variance-covariance matrix for the estimates of $\gamma 1$ and $\gamma 2$:

	lone_pensioners	IMD2007
lone_pensioners	0.031458	0.004944
IMD2007	0.004944	0.013020

TABLE 78 Table showing the impact of weakening the exclusion restrictions on the instruments in the cancer outcome equation

Coefficients on expenditure ($\widehat{\beta 1}$)		Imposed coefficient on IMD variable (γ_2)							
		−1	−0.9	−0.8	−0.7	−0.6	−0.5	−0.4	−0.3
Imposed coefficient on lone pensioner households variable (γ1)	1.00	−4.47	−4.22	−3.96	−3.71	−3.45	−3.20	−2.95	−2.70
	0.90	−4.31	−4.06	−3.80	−3.54	−3.29	−3.04	−2.79	−2.53
	0.80	−4.15	−3.90	−3.64	−3.38	−3.13	−2.88	−2.62	−2.37
	0.70	−3.99	−3.74	−3.48	−3.22	−2.97	−2.72	−2.46	−2.21
	0.60	−3.83	−3.58	−3.32	−3.06	−2.81	−2.55	−2.30	−2.05
	0.50	−3.67	−3.41	−3.16	−2.90	−2.65	−2.39	−2.14	−1.89
	0.40	−3.51	−3.25	−3.00	−2.74	−2.49	−2.23	−1.98	−1.73
	0.30	−3.35	−3.09	−2.84	−2.58	−2.32	−2.07	−1.82	−1.57
	0.20	−3.19	−2.93	−2.68	−2.42	−2.16	−1.91	−1.65	−1.40
	0.10	−3.03	−2.77	−2.51	−2.26	−2.00	−1.75	−1.49	−1.24
	0.00	−2.87	−2.61	−2.35	−2.10	−1.84	−1.58	−1.33	−1.07
	−0.10	−2.71	−2.45	−2.19	−1.93	−1.68	−1.42	−1.16	−0.91
	−0.20	−2.55	−2.29	−2.03	−1.77	−1.51	−1.26	−1.00	−0.75
	−0.30	−2.39	−2.13	−1.87	−1.61	−1.35	−1.10	−0.84	−0.58
	−0.40	−2.23	−1.97	−1.71	−1.45	−1.19	−0.93	−0.68	−0.42
	−0.50	−2.07	−1.81	−1.55	−1.29	−1.03	−0.78	−0.52	−0.27
	−0.60	−1.91	−1.65	−1.39	−1.13	−0.87	−0.62	−0.37	−0.13
	−0.70	−1.75	−1.49	−1.23	−0.97	−0.72	−0.47	−0.22	0.01
	−0.80	−1.59	−1.33	−1.07	−0.82	−0.57	−0.32	−0.09	0.14
	−0.90	−1.43	−1.17	−0.92	−0.67	−0.42	−0.18	0.05	0.27
	−1.00	−1.27	−1.02	−0.76	−0.52	−0.27	−0.04	0.18	0.41

Notes: This spreadsheet shows the value of the coefficient on expenditure ($\widehat{\beta 1}$) when estimating the cancer outcome equation [$y\times = (y - \gamma 1z1 - \gamma 2z2) = \alpha + \beta 1x + \beta 2n + \varepsilon$] using IV estimation having imposed different pairs of values for γ1 and γ2 between −1 and 1. Cells in the top left-hand quadrant contain negative values for the outcome elasticity. The outcome elasticity associated with our standard IV model (−0.34) is shown in the central square where γ1 and γ2 are, of course, zero.

–0.2	–0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
–2.45	–2.20	–1.96	–1.71	–1.47	–1.23	–0.99	–0.75	–0.50	–0.24	0.03	0.30	0.57
–2.29	–2.04	–1.80	–1.55	–1.31	–1.07	–0.83	–0.59	–0.33	–0.07	0.20	0.47	0.74
–2.13	–1.88	–1.64	–1.40	–1.16	–0.92	–0.67	–0.42	–0.16	0.10	0.37	0.65	0.92
–1.96	–1.72	–1.48	–1.24	–1.00	–0.76	–0.51	–0.26	0.01	0.28	0.55	0.82	1.10
–1.80	–1.56	–1.32	–1.08	–0.84	–0.60	–0.35	–0.09	0.18	0.45	0.73	1.00	1.28
–1.64	–1.40	–1.16	–0.92	–0.68	–0.44	–0.18	0.08	0.35	0.63	0.91	1.18	1.45
–1.48	–1.23	–0.99	–0.76	–0.52	–0.27	–0.01	0.26	0.53	0.81	1.09	1.36	1.63
–1.32	–1.07	–0.83	–0.60	–0.35	–0.10	0.16	0.44	0.71	0.99	1.26	1.53	1.80
–1.15	–0.91	–0.67	–0.43	–0.19	0.07	0.34	0.62	0.90	1.17	1.44	1.71	1.97
–0.99	–0.75	–0.51	–0.27	–0.02	0.25	0.52	0.80	1.07	1.34	1.61	1.88	2.14
–0.83	–0.58	–0.34	–0.10	0.15	0.43	0.70	0.98	1.25	1.52	1.78	2.04	2.31
–0.66	–0.42	–0.18	0.07	0.33	0.61	0.88	1.15	1.42	1.68	1.95	2.21	2.47
–0.50	–0.25	–0.01	0.24	0.51	0.79	1.06	1.32	1.59	1.85	2.11	2.37	2.63
–0.33	–0.09	0.15	0.41	0.68	0.95	1.22	1.48	1.75	2.01	2.27	2.53	2.79
–0.17	0.06	0.30	0.57	0.84	1.11	1.38	1.64	1.91	2.17	2.43	2.69	2.95
–0.03	0.20	0.44	0.72	1.00	1.27	1.54	1.80	2.06	2.32	2.58	2.84	3.10
0.10	0.32	0.58	0.87	1.15	1.42	1.69	1.95	2.22	2.48	2.74	3.00	3.26
0.22	0.46	0.73	1.02	1.30	1.57	1.84	2.11	2.37	2.63	2.89	3.16	3.42
0.35	0.60	0.88	1.17	1.45	1.72	1.99	2.26	2.52	2.79	3.05	3.31	3.57
0.50	0.76	1.04	1.32	1.60	1.88	2.15	2.41	2.68	2.94	3.20	3.47	3.73
0.65	0.92	1.20	1.48	1.76	2.03	2.30	2.57	2.83	3.09	3.36	3.62	3.88

TABLE 79 Table showing various estimates associated with the excluded instruments from the outcome equation for the big four programmes

Programme	Instrument	Coefficient	Standard error	Variance	Covariance
Cancer	*z*1: lone pensioner households	−0.2074942	0.1773647	0.0314582	0.00494454
	*z*2: IMD2007	−0.0827677	0.1141054	0.0130200	
Circulatory disease	*z*1: lone pensioner households	−0.2606290	0.2441101	0.059590	0.01122591
	*z*2: IMD2007	−0.2105334	0.2879230	0.082900	
Respiratory problems	*z*1: long-term unemployment rate	0.2642582	0.13273061	0.0176174	−0.02136305
	*z*2: LLT rate	−1.739808	1.611403	2.5966196	
Gastrointestinal problems	*z*1: unpaid carers	1.812286	2.347459	5.510564	0.08016639
	*z*2: IMD2007	0.5567431	0.2066839	0.0427822	

Second, we form the product of a pair of random numbers from the standard normal distribution (*r*1, *r*2) with the Cholesky decomposition matrix from the variance-covariance matrix for the estimates of $\gamma 1$ and $\gamma 2$. The latter is given by:

	lone_pensioners	IMD2007
lone_pensioners	0.177364	0
IMD2007	0.027877	0.110647

Finally, we add this pair of products to the respective coefficient estimates of $\gamma 1$ and $\gamma 2$ to obtain our sampled pair of values of $\gamma 1$ and $\gamma 2$ (call these $\tilde{\gamma}_1$ and $\tilde{\gamma}_2$). In other words, for each pair of random numbers (*r*1, *r*2), we calculate the sampled values $\tilde{\gamma}_1$ and $\tilde{\gamma}_2$ where:

$$\begin{bmatrix}\tilde{\gamma}_1\\ \tilde{\gamma}_2\end{bmatrix} = \begin{bmatrix}\hat{\gamma}_1\\ \hat{\gamma}_2\end{bmatrix} + \left[\begin{bmatrix}a11 & a12\\ a21 & a22\end{bmatrix} * \begin{bmatrix}r1\\ r2\end{bmatrix}\right]$$

sampled values for coefficients on excluded instruments above = coefficients from IV regressions (*Equations 19* and *20)* + Cholesky decomposition matrix * pair of random numbers from standard normal distribution

This sampling procedure is undertaken 1000 times, both with a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$, and again with a non-zero covariance.

These procedures generate two sets of 1000 pairs of values for $\hat{\gamma}_1$ and $\hat{\gamma}_2$ (one set assumes a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$, and the other does not). These sets of values for $\hat{\gamma}_1$ and $\hat{\gamma}_2$ can be used to examine the sensitivity of the estimated outcome elasticity to alternative non-zero values for the coefficients on the excluded instruments.

Obtaining the outcome elasticities associated with sampled coefficients on the excluded instruments

For each pair of sampled values of γ1 and γ2 ($\hat{\gamma}_1$ and $\hat{\gamma}_2$), we can use IV techniques to estimate the model:

$$y_{new} = y - \tilde{\gamma}1z1 - \tilde{\gamma}2z2 = \propto + \beta 1x + \beta 2n + \in \quad (21)$$

with the usual instrument set (*x*2, *z*1 and *z*2) used to instrument the endogenous variable × 1 (expenditure). For each pair of sampled values $\tilde{\gamma}_1$ and $\tilde{\gamma}_2$, we obtain a different outcome elasticity ($\widehat{\beta 1}$) and these different values can be plotted in a histogram. Such a plot illustrates the uncertainty associated with our point estimate of the outcome elasticity due to doubts about the validity of our instruments; we call this type of uncertainty 'level 2' uncertainty. This 'level 2' uncertainty is in addition to what we label 'level 1' uncertainty, that is, the uncertainty about the value of the outcome elasticity assuming the validity of our exclusion restrictions (remember that our estimated outcome elasticity is only a point estimate and that it has a distribution attached to it). To illustrate this 'level 1' uncertainty, we can sample from the distribution of the point estimate for the outcome elasticity from our basic IV model (where $\tilde{\gamma}_1$ and $\tilde{\gamma}_2$ are zero in *Equation 21*) and plot the sampled values (*Figures 16–43*).

Plots illustrating the degree of level 1 uncertainty for each of the big four programmes are shown as *Figures 16* (cancer), *23* (circulatory disease), *30* (respiratory problems) and *37* (gastrointestinal problems). These level 1 uncertainty plots can be compared with plots of $\widehat{\beta 1}$ from the estimation of *Equation 21*. The latter plots illustrate the degree of level 2 uncertainty, that is, the uncertainty associated with our point estimate of the outcome elasticity due to doubts about the validity of the instruments. *Figures 17* (cancer), *24* (circulatory disease), *31* (respiratory problems) and *38* (gastrointestinal problems) show plots of the outcome elasticity (β1 from *Equation 21*) assuming a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*. *Figures 18* (cancer), *25* (circulatory disease), *32* (respiratory problems) and *39* (gastrointestinal problems) show plots of the outcome elasticity ($\widehat{\beta 1}$ from *Equation 21*) assuming a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*.

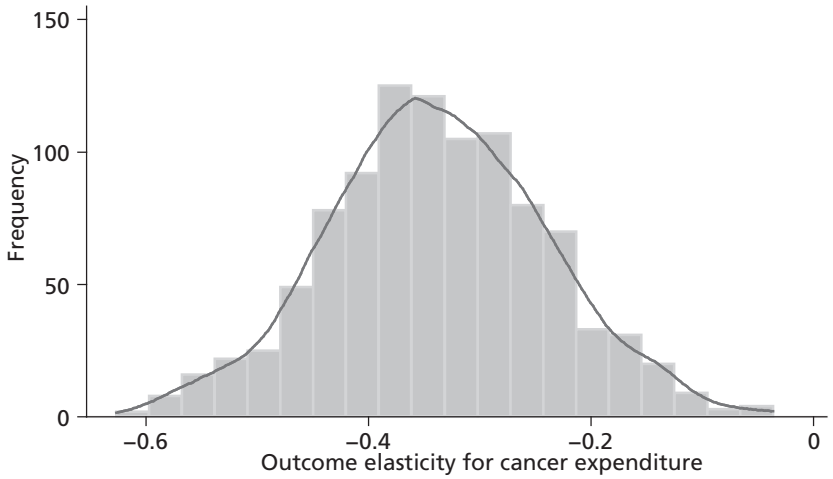


FIGURE 16 Sampling 1000 values from the distribution of the point estimate for the cancer outcome elasticity. Note: the mean value of these 1000 sampled outcome elasticities is –0.338. The outcome elasticity for cancer expenditure in the basic IV model is –0.342.

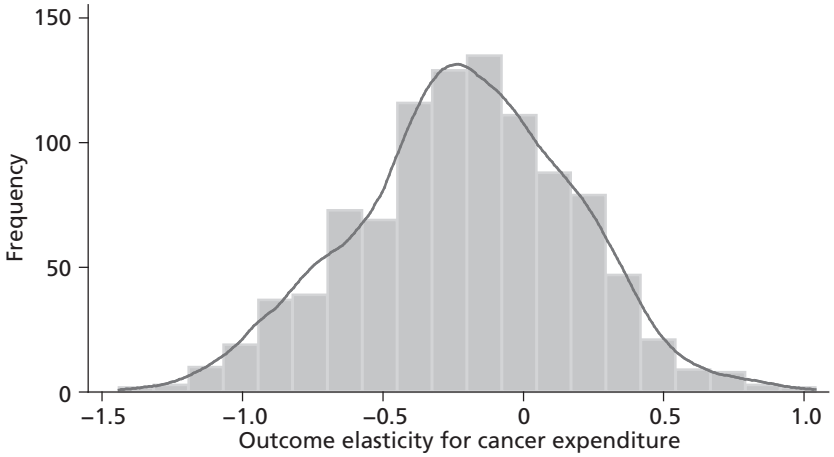


FIGURE 17 Sensitivity of the outcome elasticity for cancer expenditure to 1000 alternative pairs of coefficients on the excluded instruments with a zero covariance between these coefficients. Note: the mean value of the 1000 outcome elasticities is –0.209 (mean SE = 0.109). The outcome elasticity for cancer expenditure in the basic IV model is –0.342 (SE = 0.099). SE, standard error.

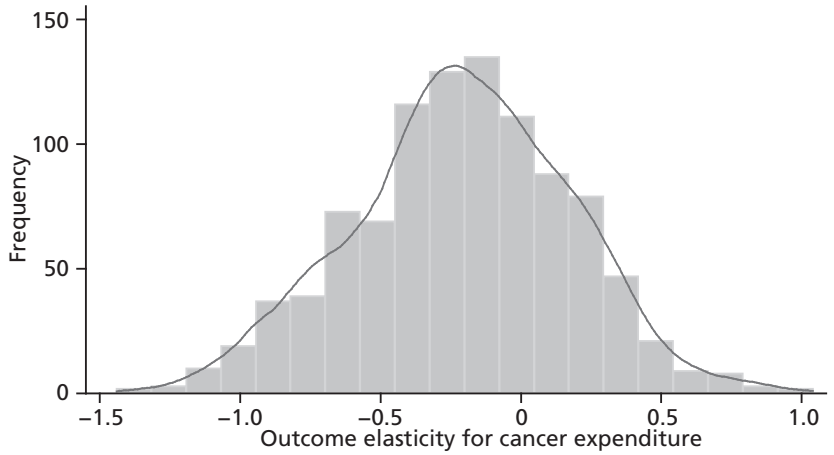


FIGURE 18 Sensitivity of the outcome elasticity for cancer expenditure to 1000 alternative pairs of coefficients on the excluded instruments with a non-zero covariance between the coefficients. Note: the mean value of the 1000 outcome elasticities is –0.209 (mean SE = 0.105). The outcome elasticity for cancer expenditure in the basic IV model is –0.342 (SE = 0.099). SE, standard error.

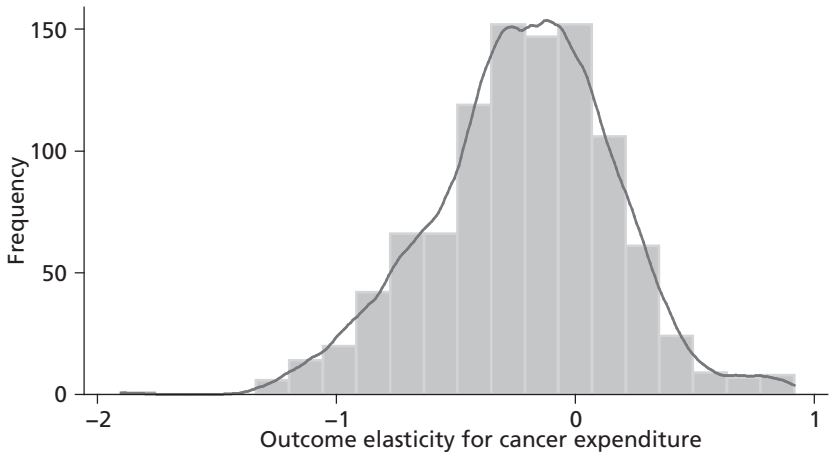


FIGURE 19 Sampling from the 1000 outcome elasticities for cancer expenditure (that were generated using 1000 alternative pairs of coefficients on the excluded instruments with a zero covariance between these coefficients). Note: the mean value of these 1000 sampled outcome elasticities is –0.220. The outcome elasticity for cancer expenditure in the basic IV model is –0.342.

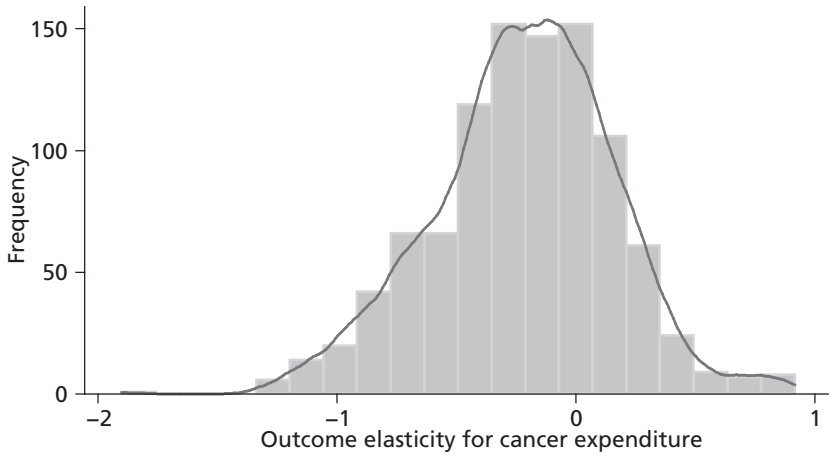


FIGURE 20 Sampling from the 1000 outcome elasticities for cancer expenditure (that were generated using 1000 alternative pairs of coefficients on the excluded instruments with a non-zero covariance between these coefficients). Note: the mean value of these 1000 sampled outcome elasticities is –0.218. The outcome elasticity for cancer expenditure in the basic IV model is –0.342.

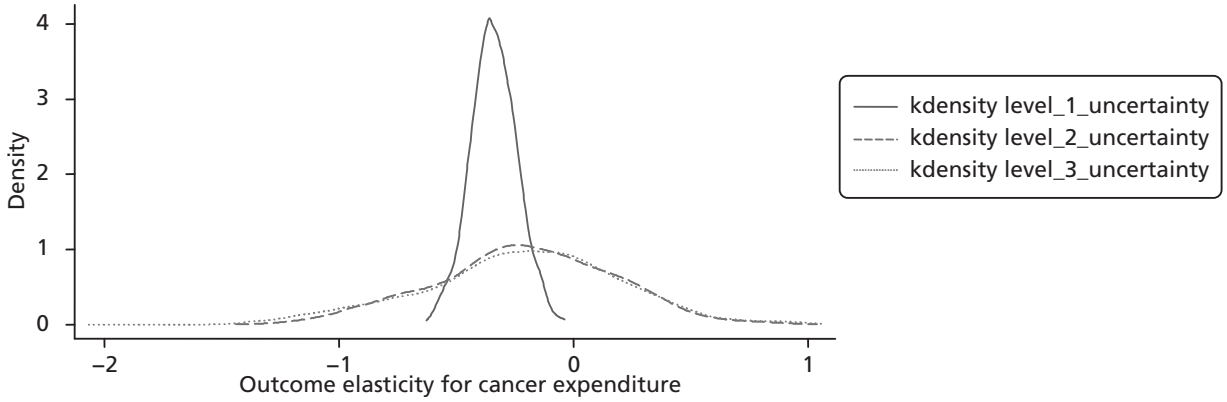


FIGURE 21 Kernel density plots from *Figures 16*, *17* and *19*: illustrating the uncertainty associated with the point estimate for the cancer outcome. Note: the mean value of the level 1/level 2/level 3 elasticities is –0.338/–0.209/–0.220. The outcome elasticity for cancer expenditure in the basic IV model is –0.342.

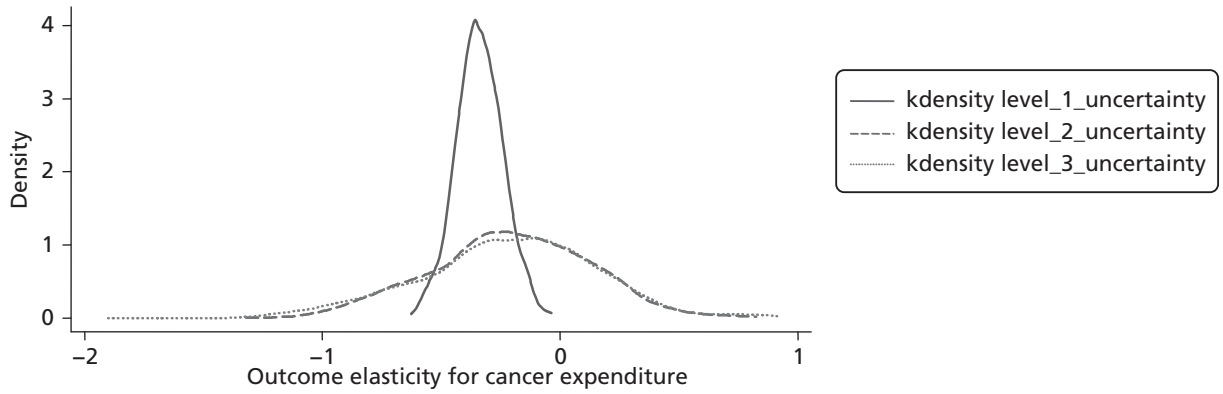


FIGURE 22 Kernel density plots from *Figures 16*, *18* and *20*: illustrating the uncertainty associated with the point estimate for the cancer outcome. Note: the mean value of the level 1/level 2/level 3 elasticities is –0.338/–0.209/–0.218. The outcome elasticity for cancer expenditure in the basic IV model is –0.342.

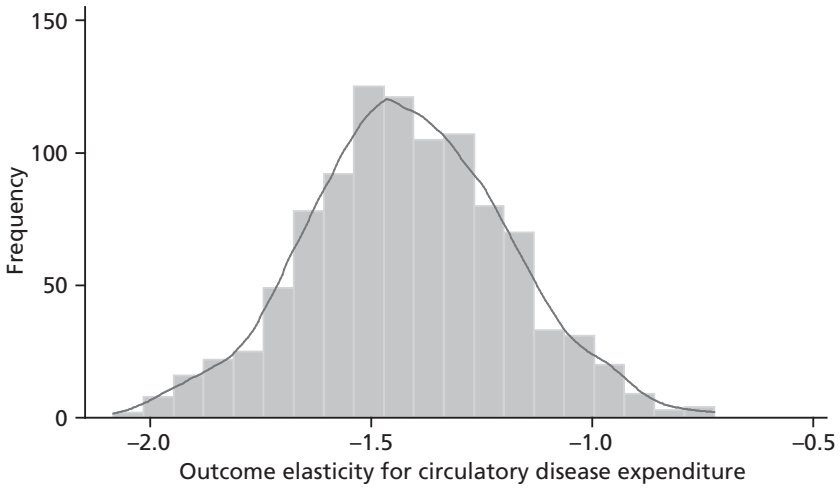


FIGURE 23 Sampling 1000 values from the distribution of the point estimate for the circulatory disease outcome elasticity. Note: the mean value of these 1000 sampled outcome elasticities is –1.418. The outcome elasticity for circulatory disease expenditure in the comparable IV model is –1.427.

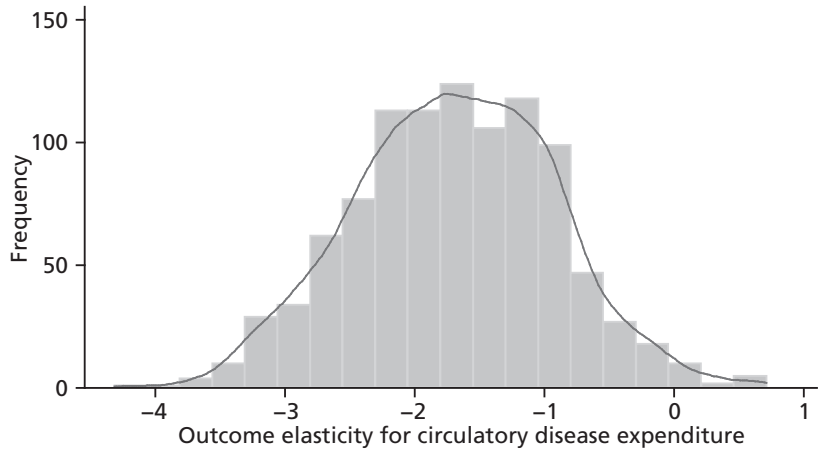


FIGURE 24 Sensitivity of the outcome elasticity for circulatory disease expenditure to 1000 alternative pairs of coefficients on the excluded instruments with a zero covariance between these coefficients. Note: the mean value of the 1000 outcome elasticities is –1.697 (mean SE = 0.269). The outcome elasticity for circulatory expenditure in the comparable IV model is –1.427 (SE = 0.228). SE, standard error.

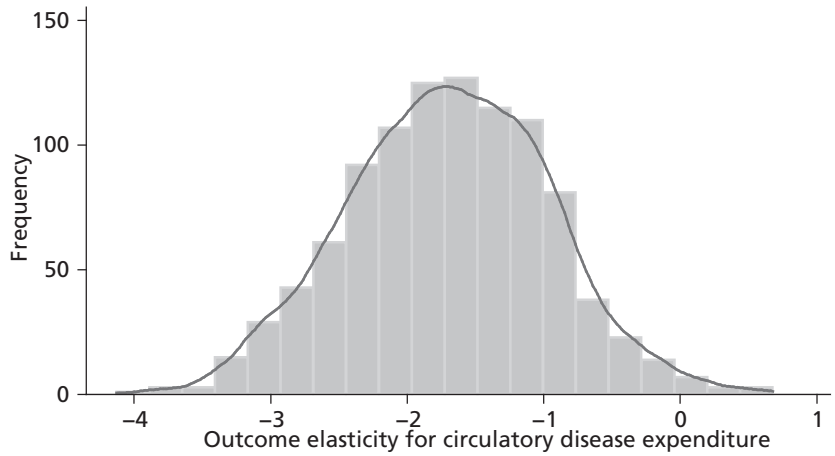


FIGURE 25 Sensitivity of the outcome elasticity for circulatory disease expenditure to 1000 alternative pairs of coefficients on the excluded instruments with non-zero covariance between the coefficients. Note: the mean value of the 1000 outcome elasticities is –1.700 (mean SE = 0.269). The outcome elasticity for circulatory expenditure in the comparable IV model is –1.427 (SE = 0.228). SE, standard error.

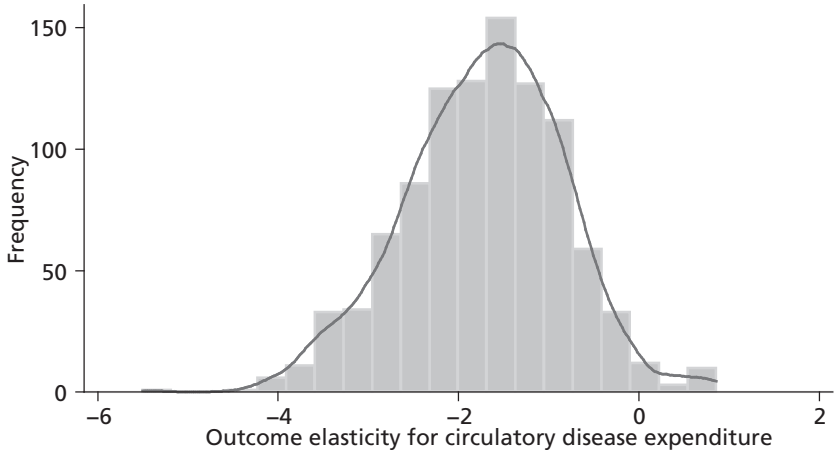


FIGURE 26 Sampling from the 1000 outcome elasticities for circulatory disease expenditure (that were generated using 1000 alternative pairs of coefficients on the excluded instruments with a zero covariance between these coefficients). Note: the mean value of these 1000 sampled outcome elasticities is –1.717. The outcome elasticity for circulatory expenditure in the comparable IV model is –1.427.

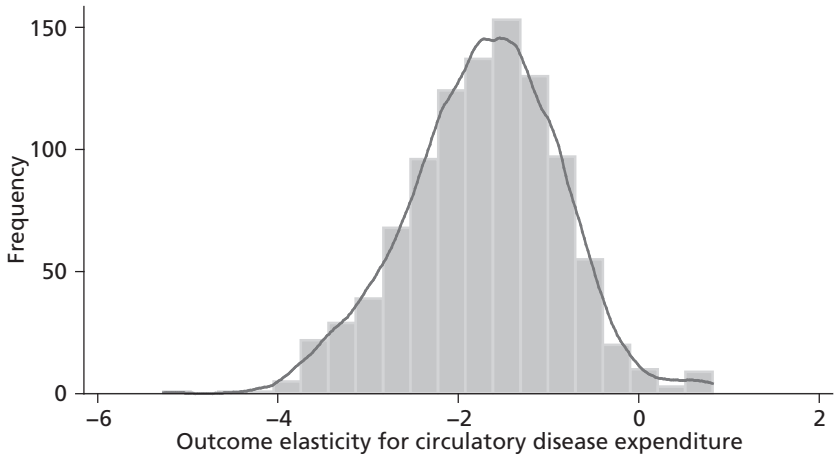


FIGURE 27 Sampling from the 1000 outcome elasticities for circulatory disease expenditure (that were generated using 1000 alternative pairs of coefficients on the excluded instruments with a non-zero covariance between these coefficients). Note: the mean value of these 1000 sampled outcome elasticities is –1.718. The outcome elasticity for circulatory expenditure in the comparable IV model is –1.427.

Finally, the point estimates $\widehat{\beta 1}$ from the estimation of *Equation 21* also have a standard error and we can sample from these distributions. These sampled values illustrate what we term 'level 3' uncertainty, that is, the uncertainty associated with the value of the outcome elasticity due to both level 1 (sampling) and level 2 (instrument invalidity) effects.

Plots illustrating the degree of level 3 uncertainty, assuming a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*, are shown as *Figures 19* (cancer), *26* (circulatory disease), *33* (respiratory problems) and *40* (gastrointestinal problems). Plots illustrating the degree of level 3 uncertainty, assuming a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*, are shown as *Figures 20* (cancer), *27* (circulatory disease), *34* (respiratory problems) and *41* (gastrointestinal problems).

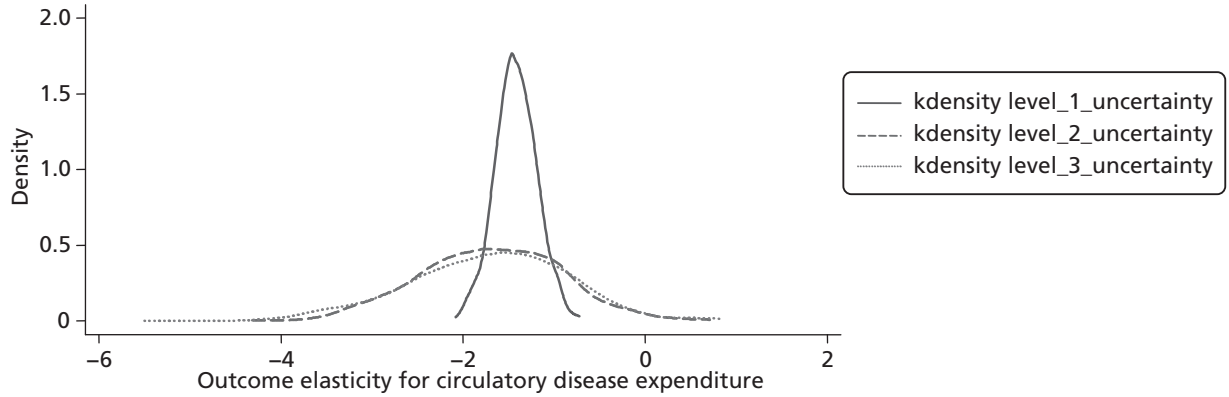


FIGURE 28 Kernel density plots from *Figures 23*, *24* and *26*: illustrating the uncertainty associated with the point estimate for the circulatory disease outcome elasticity. Note: the mean value of the level 1/level 2/level 3 elasticities is –1.418/–1.697/–1.717. The outcome elasticity for circulatory disease expenditure in the comparable IV model is –1.427.

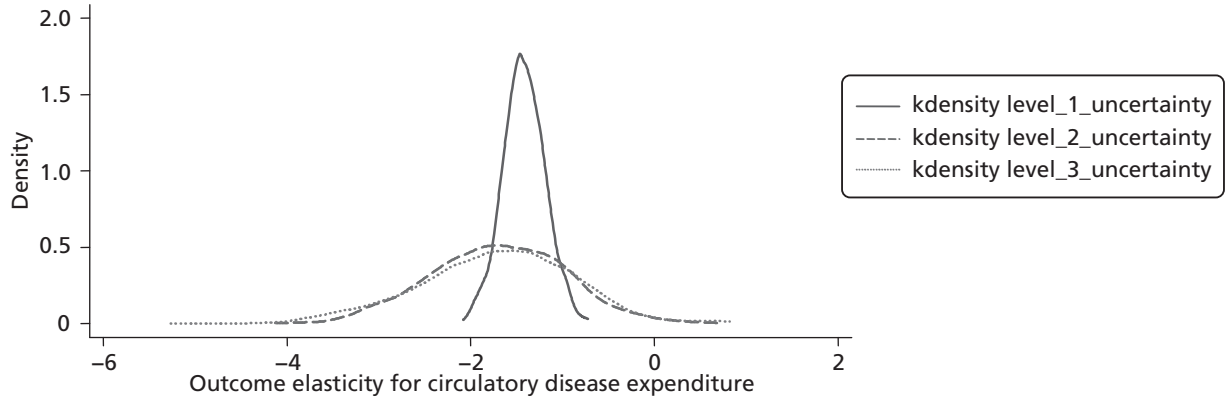


FIGURE 29 Kernel density plots from *Figures 23*, *25* and *27*: illustrating the uncertainty associated with the point estimate for the circulatory disease outcome elasticity. Note: the mean value of the level 1/level 2/level 3 elasticities is –1.418/–1.700/–1.718. The outcome elasticity for circulatory disease expenditure in the comparable IV model is –1.427.

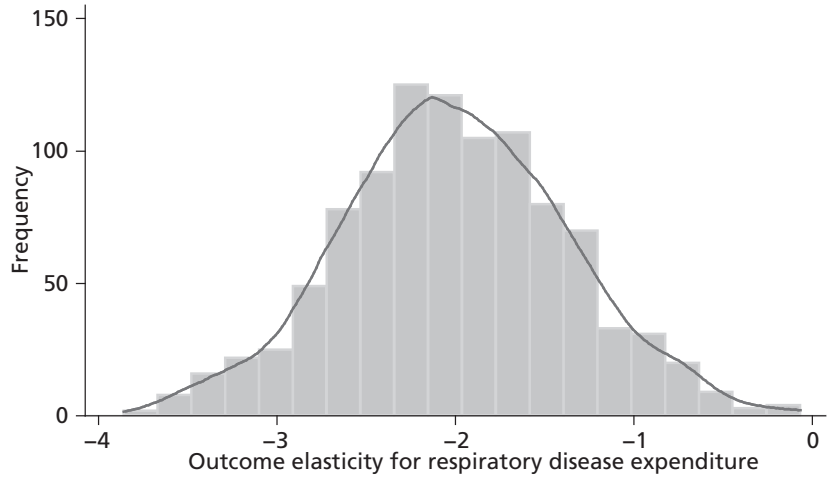


FIGURE 30 Sampling 1000 values from the distribution of the point estimate for the respiratory disease outcome elasticity. Note: The mean value of these 1000 sampled outcome elasticities is –2.004. The outcome elasticity for respiratory expenditure in the comparable IV model is –2.029.

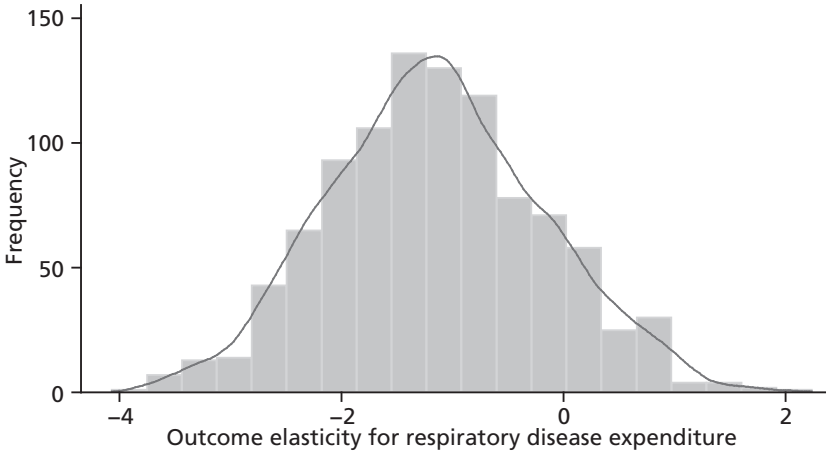


FIGURE 31 Sensitivity of the outcome elasticity for respiratory disease expenditure to 1000 alternative pairs of coefficients on the excluded instruments with a zero covariance between these coefficients. Note: the mean value of the 1000 outcome elasticities is –1.145 (mean SE = 0.489). The outcome elasticity for respiratory expenditure in the comparable IV model is –2.029 (SE = 0.636). SE, standard error.

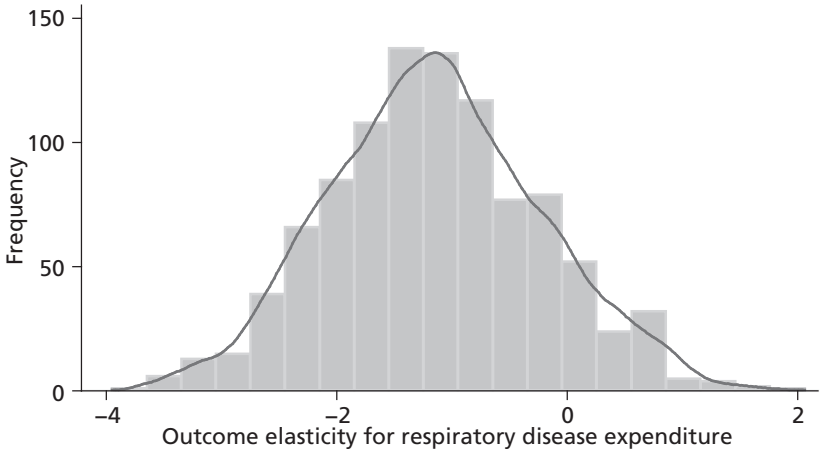


FIGURE 32 Sensitivity of the outcome elasticity for respiratory disease expenditure to 1000 alternative pairs of coefficients on the excluded instruments with a non–zero covariance between the coefficients. Note: the mean value of the 1000 outcome elasticities is –1.149 (mean SE = 0.485). The outcome elasticity for respiratory expenditure in the comparable IV model is –2.029 (SE = 0.636). SE, standard error.

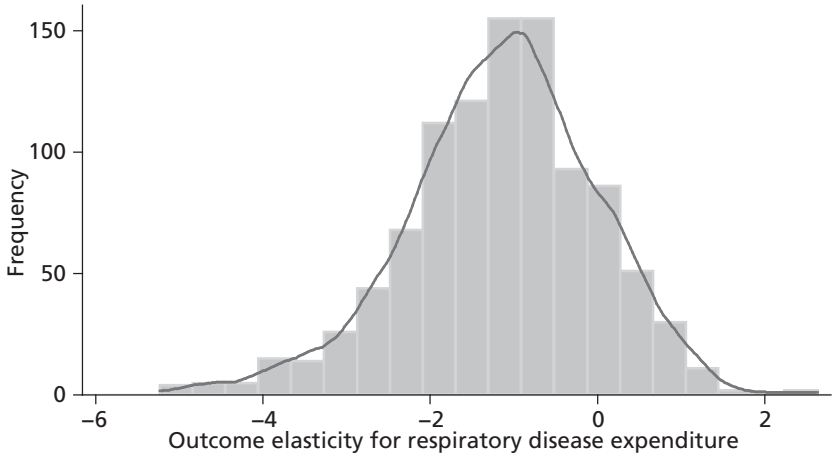


FIGURE 33 Sampling from the 1000 outcome elasticities for respiratory disease expenditure (that were generated using 1000 alternative pairs of coefficients on the excluded instruments with a zero covariance between these coefficients). Note: the mean value of these 1000 sampled outcome elasticities is –1.146. The outcome elasticity for respiratory expenditure in the comparable IV model is –2.029.

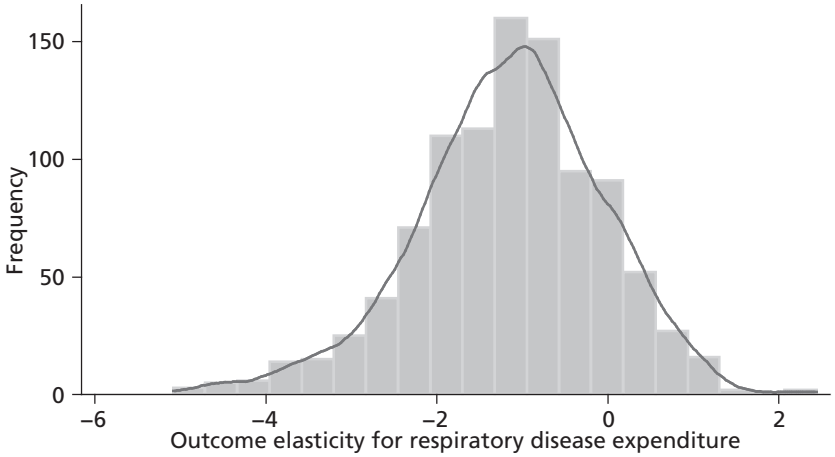


FIGURE 34 Sampling from the 1000 outcome elasticities for respiratory disease expenditure (that were generated using 1000 alternative pairs of coefficients on the excluded instruments with a non-zero covariance between these coefficients). Note: the mean value of these 1000 sampled outcome elasticities is –1.151. The outcome elasticity for respiratory expenditure in the comparable IV model is –2.029.

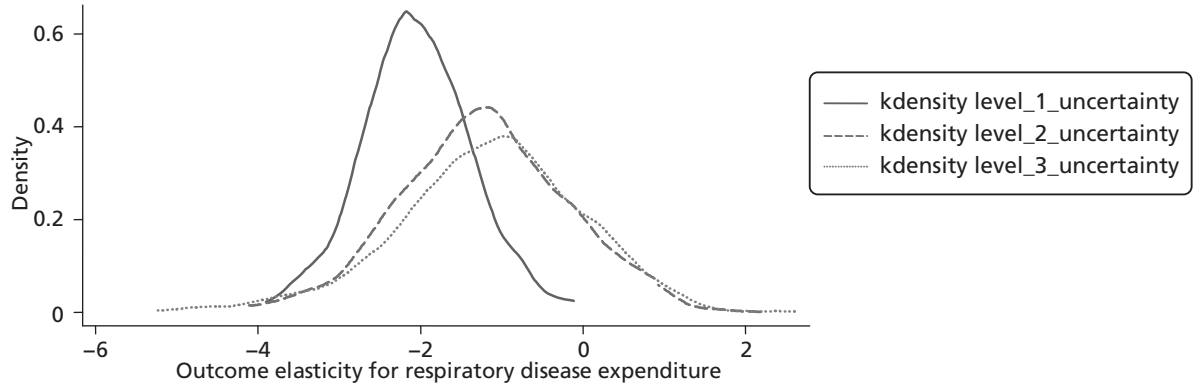


FIGURE 35 Kernel density plots from *Figures 30*, *31* and *33*: illustrating the uncertainty associated with the point estimate for the respiratory disease outcome elasticity. Note: the mean value of the level 1/level 2/level 3 elasticities is –2.004/–1.145/–1.146. The outcome elasticity for respiratory disease expenditure in the comparable IV model is –2.029.

Uncertainty and the value of the cancer outcome elasticity

Figure 16 plots 1000 values from the distribution of the point estimate for the cancer outcome elasticity. The mean value of these sampled values is –0.338 (the outcome elasticity in the basic IV model is –0.342 and its standard error is 0.099) and virtually all of them lie between 0 and –0.6.

The histogram in *Figure 17* provides a plot of 1000 point estimates for the cancer outcome elasticity if we drop the assumption that the coefficients on the excluded instruments are exactly zero (and we also assume a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). The mean value of these 1000 outcome elasticities is –0.209 and this is about one-third lower than the elasticity in the basic IV model (–0.342). In addition, the mean value of the standard errors associated with these 1000 elasticities (0.109) is slightly greater than the standard error in the basic IV model (0.099) so that about one-quarter of the outcome elasticities in *Figure 17* take a non-negative value.

The histogram in *Figure 18* provides a similar plot to that in *Figure 17* but this time we assume a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*. There is very little difference between the zero (see *Figure 17*) and non-zero (see *Figure 18*) covariance plots, with both the mean elasticity and mean standard error virtually identical in both plots.

The histograms in *Figures 17* and *18* provide plots of the point estimate for the cancer outcome elasticity if we drop the assumption that the coefficients on the excluded instruments are exactly zero. Each point estimate also has a standard error and we can sample from these estimates and their distributions to obtain the histograms shown in *Figures 19* and *20*. With the exception of a slight lengthening in the tail on the left hand side, these plots are very similar to the plots in *Figures 17* and *18*.

Figure 21 reproduces the three kernel density plots shown in *Figures 16*, *17* and *19* (remember that *Figures 17* and *19* assume a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). Together these plots illustrate the impact of all three levels of uncertainty on our estimate of the cancer outcome elasticity. It is clear that the uncertainty induced by the instrument validity issue considerably increases the uncertainty associated with our estimate of the outcome elasticity (compare, for example, the density plot for level 1 uncertainty with those for both level 2 and level 3 uncertainty).

Figure 22 reproduces the three kernel density plots shown in *Figures 16*, *18* and *20* (remember that *Figures 18* and *20* assume a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). As is the case for *Figure 21*, these plots illustrate the impact of all three levels of uncertainty on our estimate of the cancer outcome elasticity and, again, it is clear that it is the uncertainty induced by the instrument validity issue that considerably increases the uncertainty associated with our estimate of the outcome elasticity. For example, the standard deviation associated with the level 1 uncertainty density plot is 0.099 but the

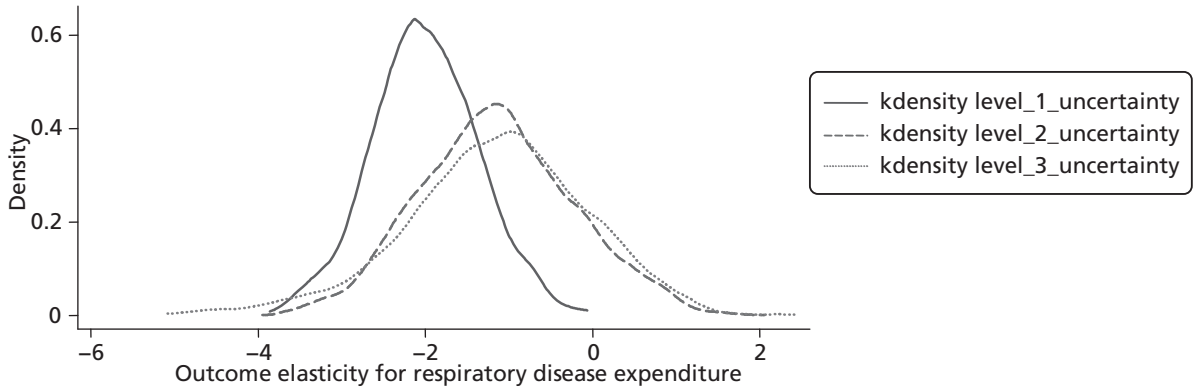


FIGURE 36 Kernel density plots from *Figures 30*, *32* and *34*: illustrating the uncertainty associated with the point estimate for the respiratory disease outcome elasticity. Note: the mean value of the level 1/level 2/level 3 elasticities is –2.004/–1.149/–1.151. The outcome elasticity for respiratory disease expenditure in the comparable IV model is –2.029.

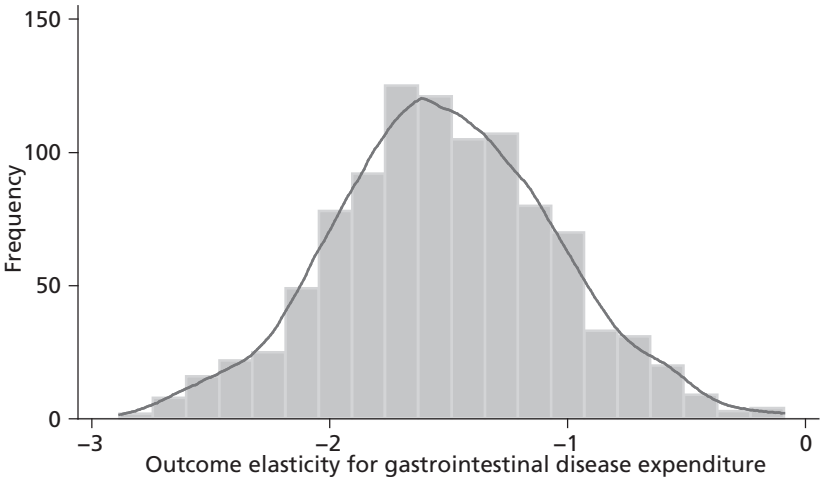


FIGURE 37 Sampling 1000 values from the distribution of the point estimate for the gastrointestinal disease outcome elasticity. Note: the mean value of these 1000 sampled outcome elasticities is –1.518. The outcome elasticity for gastrointestinal expenditure in the comparable IV model is –1.536.

standard deviation for the level 2 (0.338) and level 3 (0.379) uncertainty density plots are both considerably larger than this.

Uncertainty and the value of the circulatory disease outcome elasticity

Figure 23 plots 1000 values from the distribution of the point estimate for the circulatory disease outcome elasticity. The mean value of these sampled values is −1.418 and virtually all of these values lie between −2.0 and −0.75. The outcome elasticity in the comparable IV model is −1.427.[ah]

The histogram in *Figure 24* provides a plot of 1000 point estimates for the circulatory disease outcome elasticity if we drop the assumption that the coefficients on the excluded instruments are exactly zero (and we also assume a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). The mean value of these 1000 outcome elasticities is −1.697 and this is about one-fifth larger than the elasticity in the comparable IV model (−1.427). Similarly, the mean value of the standard errors associated with these 1000 elasticities (0.269) is also about one-fifth larger than the standard error in the comparable basic IV model (0.228). Virtually all of the point estimates values lie between −4.0 and 0.0, and there are very few non-negative values.

The histogram in *Figure 25* provides a similar plot to that in *Figure 24* but this time we assume a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*. There is very little difference between the zero (see *Figure 24*) and non-zero (see *Figure 25*) covariance plots, with both the mean elasticity and mean standard error virtually identical in both plots.

The histograms in *Figures 24* and *25* provide plots of the point estimate for the circulatory disease outcome elasticity if we drop the assumption that the coefficients on the excluded instruments are exactly zero. Each point estimate also has a standard error and we can sample (with replacement) from these estimates and their distributions to obtain the histograms shown in *Figures 26* and *27*. With the exception of a slight lengthening in the tail on the left hand side (as was also observed for the cancer programme), these plots are very similar to the plots in *Figures 24* and *25*.

Figure 28 reproduces the three kernel density plots shown in *Figures 23*, *24* and *26* (remember that *Figures 24* and *26* assume a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). Together these plots illustrate the impact of all three levels of uncertainty on our estimate of the circulatory disease outcome elasticity. It is clear that the uncertainty induced by the instrument validity issue considerably increases the uncertainty associated with our estimate of the outcome elasticity (note that the range of values increases dramatically from the density plot illustrating level 1 uncertainty to that illustrating level 2 uncertainty).

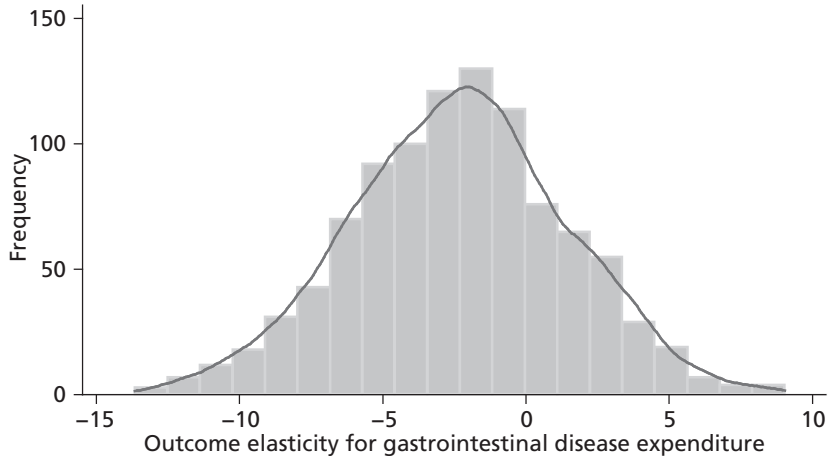


FIGURE 38 Sensitivity of the outcome elasticity for gastrointestinal disease expenditure to 1000 alternative pairs of coefficients on the excluded instruments with a zero covariance between these coefficients. Note: the mean value of the 1000 outcome elasticities is –2.365 (mean SE = 0.853). The outcome elasticity for gastrointestinal expenditure in the basic IV model is –1.536 (SE = 0.468). SE, standard error.

Figure 29 reproduces the three kernel density plots from *Figures 23*, *25* and *27* (remember that *Figures 25* and *27* assume a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). As is the case for *Figure 28*, these plots illustrate the impact of all three levels of uncertainty on our estimate on the circulatory disease outcome elasticity and, again, it is clear that it is the uncertainty induced by the instrument validity issue that considerably increases the uncertainty associated with our estimate of the outcome elasticity. For example, the standard deviation associated with the level 1 uncertainty density plot is 0.228 but the standard deviation for the level 2 (0.735) and level 3 (0.843) uncertainty density plots are both considerably larger than this.

Uncertainty and the value of the respiratory disease outcome elasticity

Figure 30 plots 1000 values from the distribution of the point estimate for the respiratory disease outcome elasticity [see column (5) of *Table 65*]. The mean value of these sampled values is –2.004 (the outcome elasticity in the comparable IV model is –2.029) and all of these values lie between –4.0 and 0.

The histogram in *Figure 31* provides a plot of 1000 point estimates for the respiratory disease outcome elasticity if we drop the assumption that the coefficients on the excluded instruments are exactly zero (and we also assume a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). The mean value of these 1000 outcome elasticities from the respiratory disease outcome model (–1.145) is almost one-half of the size of the elasticity in the comparable basic IV model (–2.029). And the mean value of the standard errors associated with these 1000 elasticities (0.489) is about one-quarter less than the standard error in the comparable basic IV model (0.636).

The histogram in *Figure 32* provides a similar plot to that in *Figure 31* but this time we assume a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*. However, there is very little difference between the zero (see *Figure 31*) and non-zero (see *Figure 32*) covariance plots, with both the mean elasticity and mean standard error virtually identical in these two plots.

The histograms in *Figures 31* and *32* provide plots of the point estimate for the respiratory disease outcome elasticity if we drop the assumption that the coefficients on the excluded instruments are exactly zero. Each point estimate also has a standard error and we can sample from these estimates and their distributions to obtain the histograms shown in *Figures 33* and *34*. With the exception of a slight lengthening of the tail on the left-hand side, these plots are similar to those in *Figures 31* and *32* so the sampling procedure would appear to have little impact on the distribution of the point elasticities.

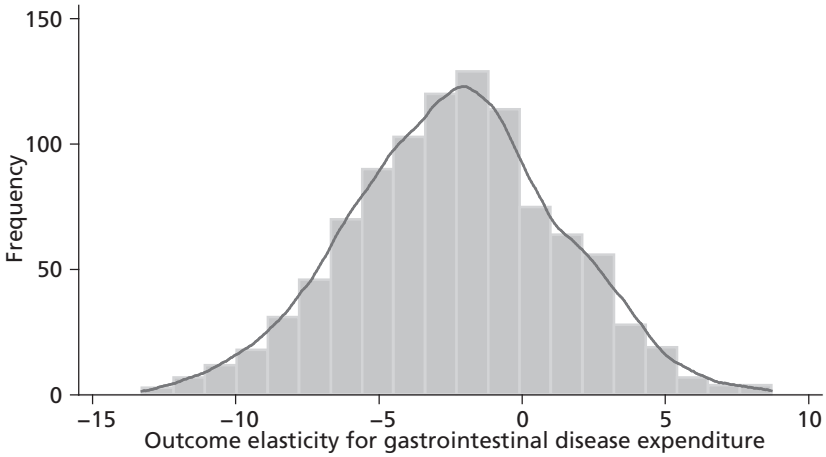


FIGURE 39 Sensitivity of the outcome elasticity for gastrointestinal disease expenditure to 1000 alternative pairs of coefficients on the excluded instruments with non-zero covariance between the coefficients. Note: the mean value of the 1000 outcome elasticities is –2.360 (mean SE = 0.839). The outcome elasticity for gastrointestinal expenditure in the basic IV model is –1.536 (SE = 0.468). SE, standard error.

Figure 35 reproduces the three kernel density plots shown in *Figures 30*, *31* and *33* (remember that *Figures 31* and *33* assume a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). Together these plots illustrate the impact of all three levels of uncertainty on our estimate of the respiratory disease outcome elasticity. It is clear that the uncertainty induced by the instrument validity issue both shifts the density plot to the right and increases the uncertainty associated with our estimate of the outcome elasticity (e.g. the range of values increases from –4.0 to 0.0 at level 1 to –5.0 to 2.5 at level 3).

Figure 36 reproduces the three kernel density plots shown in *Figures 30*, *32* and *34* (remember that *Figures 32* and *34* assume a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). As is the case for *Figure 35*, these plots illustrate the impact of all three levels of uncertainty on our estimate of the respiratory disease outcome elasticity and, again, it is clear that the uncertainty induced by the instrument validity issue both shifts the density plot to the right and considerably increases the uncertainty associated with our estimate of the outcome elasticity. More precisely, the standard deviation associated with the level 1 uncertainty density plot is 0.636 but the standard deviation for the level 2 (0.919) and level 3 (1.098) uncertainty density plots are both considerably larger than this.

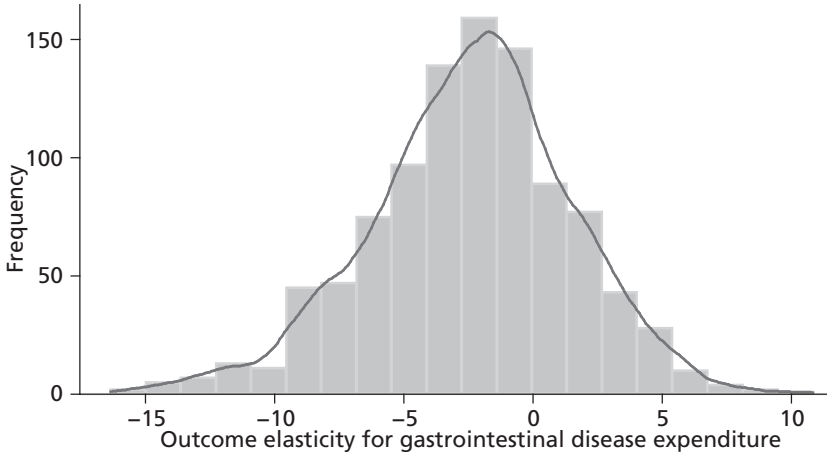


FIGURE 40 Sampling from the 1000 outcome elasticities for gastrointestinal disease expenditure (that were generated using 1000 alternative pairs of coefficients on the excluded instruments with a zero covariance between these coefficients). Note: the mean value of these 1000 sampled outcome elasticities is –2.442. The outcome elasticity for gastrointestinal expenditure in the comparable IV model is –1.536.

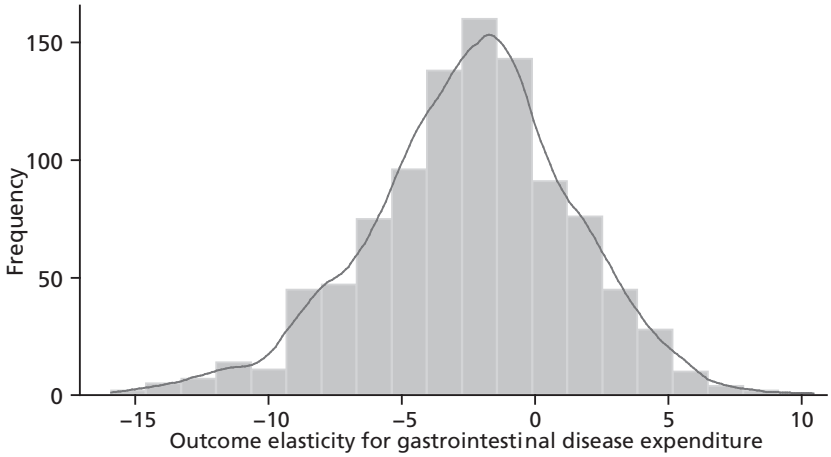


FIGURE 41 Sampling from the 1000 outcome elasticities for gastrointestinal disease expenditure (that were generated using 1000 alternative pairs of coefficients on the excluded instruments with a non-zero covariance between these coefficients). Note: the mean value of these 1000 sampled outcome elasticities is –2.434. The outcome elasticity for gastrointestinal expenditure in the comparable IV model is –1.536.

Uncertainty and the value of the gastrointestinal disease outcome elasticity

Figure 37 plots 1000 values from the distribution of the point estimate for the gastrointestinal disease outcome elasticity [see column (7) of *Table 65*]. The mean of these sampled values is −1.518 (the outcome elasticity in the comparable IV model is −1.536) and all of these values lie between −3.0 and 0.0.

The histogram in *Figure 38* provides a plot of 1000 point estimates for the gastrointestinal disease outcome elasticity if we drop the assumption that the coefficients on the excluded instruments are exactly zero (and we also assume a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). The mean value of these 1000 outcome elasticities (−2.365) is 50% larger than the size of the elasticity in the comparable IV model (−1.536). And the mean value of the standard errors associated with these 1000 elasticities (0.853) is about 80% larger than the standard error in the basic IV model (0.468).

The histogram in *Figure 39* provides a similar plot to that in *Figure 38*, but this time we assume a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*. However, there is very little difference between the zero (see *Figure 38*) and non-zero (see *Figure 39*) covariance plots, with both the mean elasticity and mean standard error virtually identical in these plots.

The histograms in *Figures 38* and *39* provide plots of point estimates for the gastrointestinal disease outcome elasticity if we drop the assumption that the coefficients on the excluded instruments are exactly zero. Each point estimate also has a standard error and we can sample from these estimates and their distributions to obtain the histograms shown in *Figures 40* and *41*. With the exception of a slight extension to both tails, these plots are similar to the plots in *Figures 38* and *39*.

Figure 42 reproduces the three kernel density plots shown in *Figures 37*, *38* and *40* (remember that *Figures 38* and *40* assume a zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). These plots illustrate the impact of all three levels of uncertainty on our estimate of the gastrointestinal disease outcome elasticity. It is clear that the uncertainty induced by the instrument validity issue both shifts the density plot to the left slightly and dramatically increases the uncertainty associated with our estimate of the outcome elasticity (e.g. the range of values increases from −3 to 0 at level 1, from −13 to 9 at level 2, and then further from −16 to 11 at level 3).

Figure 43 reproduces the three kernel density plots shown in *Figures 37*, *39* and *41* (remember that *Figures 39* and *41* assume a non-zero covariance between $\hat{\gamma}_1$ and $\hat{\gamma}_2$ in *Equations 18* and *19*). As is the case for *Figure 42*, these plots illustrate the impact of all three levels of uncertainty on our estimate of the gastrointestinal disease outcome elasticity. And again, it is clear that the uncertainty induced by the instrument validity issue both shifts the density plot to the left slightly and considerably increases the uncertainty (range) associated with our estimate of the outcome elasticity. More precisely, the standard

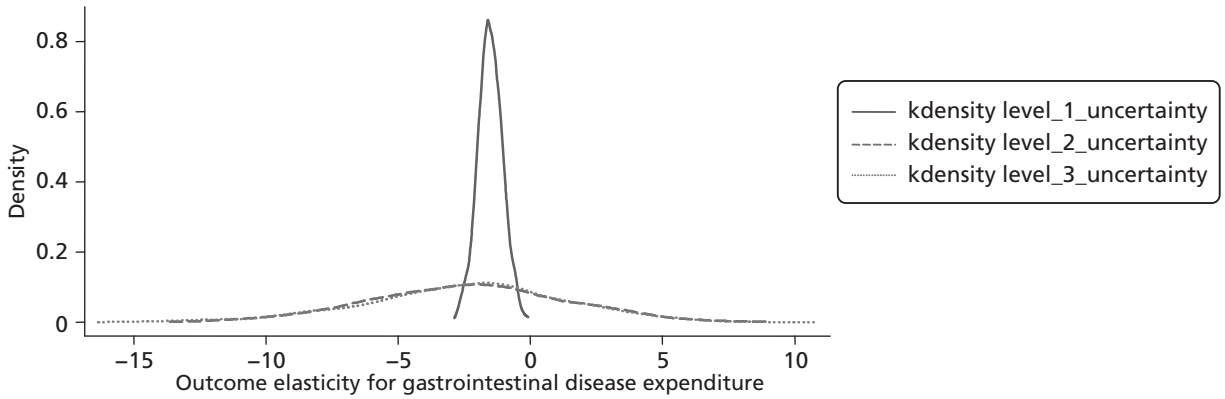


FIGURE 42 Kernel density plots from *Figures 37*, *38* and *40*: illustrating the uncertainty associated with the point estimate for the gastrointestinal disease outcome elasticity. Note: the mean value of the level 1/level 2/level 3 elasticities is −1.518/−2.365/−2.442. The outcome elasticity for gastrointestinal expenditure in the comparable IV model is −1.536.

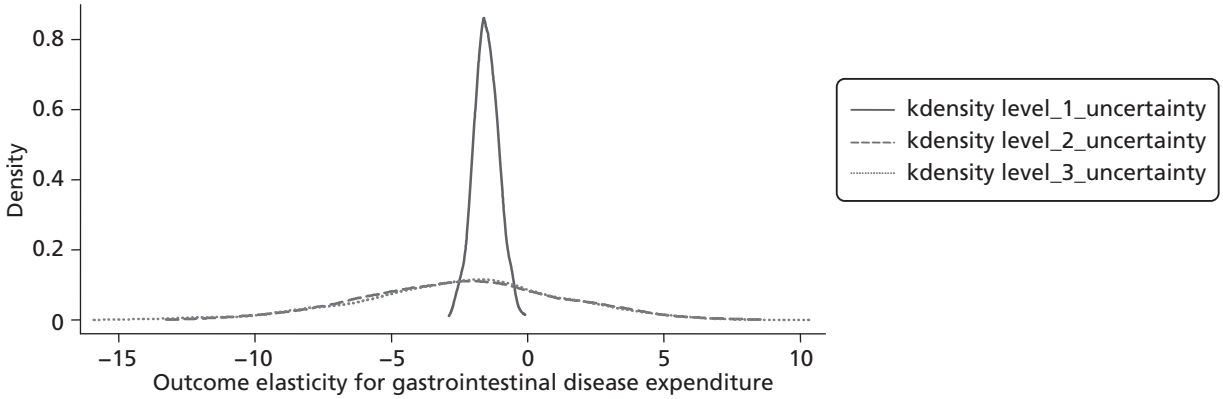


FIGURE 43 Kernel density plots from *Figures 37*, *39* and *41*: illustrating the uncertainty associated with the point estimate for the gastrointestinal disease outcome elasticity. Note: the mean value of the level 1/level 2/level 3 elasticities is −1.518/−2.360/−2.434. The outcome elasticity for gastrointestinal expenditure in the comparable IV model is −1.536.

deviation associated with the level 1 uncertainty density plot is 0.468 but the standard deviation for the level 2 (3.658) and level 3 (3.834) uncertainty density plots are both eight times larger than this.

Implications of uncertainty for the estimate of the cost of a life-year

In the previous subsection, we have evaluated the outcome equation elasticities when uncertainty over the validity of instrument variables is considered ('level 3' uncertainty), in contrast to assuming the instruments are valid ('level 1' uncertainty). This analysis showed that including level 3 uncertainty affects the central value of the outcome elasticities; however, it is difficult to predict its effect on the expectation of the threshold given the impact of expenditure on mortality appears reduced in some programmes but increased in others. In *Table 80*, the mean estimates of the outcome elasticities under level 3 uncertainty were used to calculate the threshold for the big four programmes of health. The results show that relaxing the assumption of validity of the instruments has little impact on the expectation of the threshold for the big four PBCs [the cost per YLG threshold changed from £10,604 (see *Table 68*) to £11,009 (see *Table 80*)].

The assumption of validity of instruments is expected to affect significantly the level of uncertainty over the cost-effectiveness threshold estimate. Illustrations of this source of uncertainty were presented in the previous section (see *Obtaining the outcome elasticities associated with sampled coefficients on the excluded instruments*) using empirical distributions derived from the sampling procedure implemented; these illustrations represent the uncertainty in the mean estimate for each of the elasticities. To characterise the effect of levels 1 and 3 uncertainty on the overall threshold we used the sets of simulated elasticities (one for each of the four programmes of care) to compute a threshold value; in doing so for all simulated sets, a sample of threshold values was obtained. In this way, uncertainty was propagated from the outcome elasticities to the threshold estimates, and an empirical distribution describing uncertainty over threshold estimates obtained. The cumulative density function can be used to display such uncertainty; this plots the probability (*y*-axis) of the threshold being below certain values (*x*-axis) in the simulated sample (this corresponds to a Bayesian interpretation of uncertainty). *Figure 44* plots the cumulative density curve for the cost per life gained threshold when level 1 and level 3 uncertainty are considered in turn, and *Figure 45* for the cost per YLG threshold.

The probability that the overall threshold is < £7500 per life-year is around 0.2 when uncertainty over the validity of instruments is considered (level 3), whereas when the instruments are assumed valid (level 1) this probability is 0. Under level 1 uncertainty, we would be confident that the threshold is < £30,000 (probability of 1), but when considering level 3 uncertainty there is some chance that the threshold is > £30,000 (probability of 0.2). These plots show that uncertainty on the validity of the instruments generates significant uncertainty over the threshold value.

TABLE 80 Cost of life and life-year estimates for the big four programmes using expenditure data for 2006 and outcome data for 2006/7/8 adjusted for the ICD-10 coverage of the expenditure and outcome data

PBC description	Spend (£M) 2006/7	Spend elasticity	Change in spend (£M)	Annual mortality, < 75 years, 2006/7/8	Outcome elasticity (without negative sign)	Coverage of mortality data relative to spend data	Change in annual mortality adjusted for coverage	Cost per life gained (£) adjusted for coverage	Total life-years lost, < 75 years, 2006/7/8	Coverage of mortality data relative to spend data	Change in annual life-years lost adjusted for YLL	Cost per YLG (£)	Cost per YLG adjusted for YLL coverage (£)
1 Cancer	4122	0.465	19.17	61,961	0.218	0.984	63.90	299,975	2,207,021	0.984	759	16,383	25,265
2 Circulatory problems	6161	0.540	33.27	41,106	1.718	0.992	384.42	86,544	1,361,634	0.992	4245	9466	7838
3 Respiratory problems	3285	0.679	22.31	11,574	1.151	0.773	116.99	190,666	324,223	0.773	1092	11,593	20,419
4 Gastrointestinal problems	3700	0.446	16.50	6160	2.434	0.571	117.11	140,906	345,908	0.571	2192	20,892	7528
5 Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801			682.42	133,707	4,238,786		8288	12,333	11,009

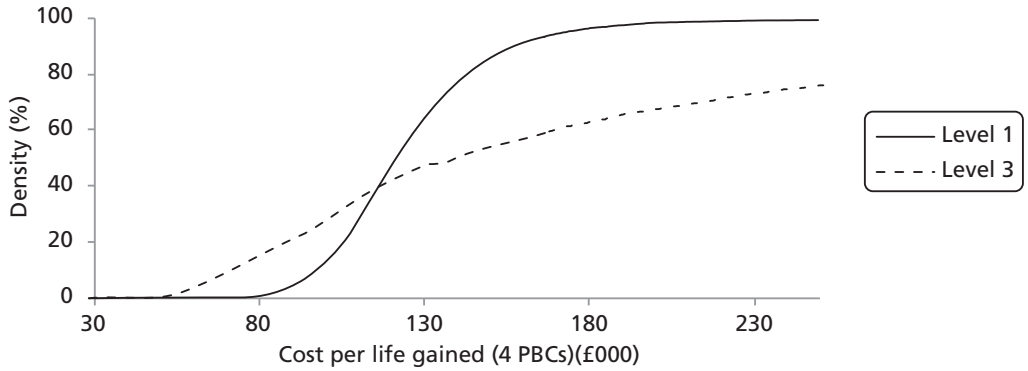


FIGURE 44 Cumulative density plot for the cost per life gained threshold for the big four PBCs (considers covariance between the coefficients on the excluded instruments). In drawing the cumulative density function, negative threshold values were dealt with by evaluating whether it was the health component or the cost component that was negative. For simulations where health change was negative (0% were observed for both levels 1 and 3), the threshold was left as a negative value. Simulations showing a negative change in spend were assigned a very high positive threshold value – in these an asymptote is generated in the plot (respectively 0% and 5.6% were observed for levels 1 and 3).

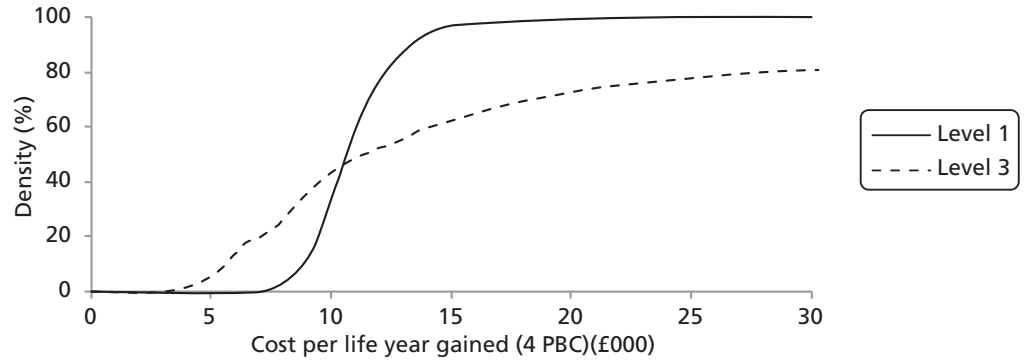


FIGURE 45 Cumulative density plot for the cost per YLG threshold for the big four PBCs (considers covariance between the coefficients on the excluded instruments). In drawing the cumulative density function, negative threshold values were dealt with by evaluating whether it was the health component or the cost component that was negative. For simulations where health change was negative (0% were observed for both levels 1 and 3), the threshold was left as a negative value. Simulations showing a negative change in spend were assigned a very high positive threshold value – in these an asymptote is generated in the plot (respectively 0.04% and 7.7% were observed for levels 1 and 3).

Summary and conclusion

One of the crucial elements in the calculation of the cost of a life-year for any care programme is the coefficient on the expenditure variable in the outcome equation. The endogenous nature of expenditure in our model means that OLS estimation is inappropriate and that instead IV techniques must be used. The application of these techniques requires the identification of variables that are good predictors of the endogenous variable (expenditure) but which do not have a direct effect on the dependent variable (mortality).

It is difficult to provide theoretical arguments why our selected instruments will not affect mortality directly. Instead, we rely on the widely used Hansen–Sargen test of instrument validity. Although our models 'pass' this test, some commentators have argued that this test has weak power and may fail to reject the null hypothesis of instrument validity even when an exclusion restriction is not valid. Given our reliance on this test, we noted that this test will only lack power if the biases induced in the coefficient on the endogenous variable by invalid instruments all coincide (i.e. the instruments all identify the *same* wrong parameter). However, it is far from obvious that this will be so in this case, particularly given that our outcome equation already includes a measure of the need for health care.

Nevertheless, it is possible that our instruments are correlated with both expenditure and some unobserved factor which is directly influencing the mortality rate, and that the induced bias in $\widehat{\beta 1}$ is the same for both instruments.

We therefore undertook an extensive sensitivity analysis of the estimated outcome elasticity to the validity of the exclusion restrictions. In summary, we found that both the central value and distribution of the outcome elasticity may change if we drop the assumption that the coefficients on the excluded instruments are identically zero.

This change in the central value of the outcome elasticity reduces the impact of expenditure on mortality in some programmes (e.g. for cancer the 'average' outcome elasticity falls from –0.338 to –0.210, and for respiratory disease it falls from –2.004 to –1.151). However, in other programmes this change in the central value increases the impact of expenditure on mortality (e.g. for circulatory disease the 'average' outcome elasticity increases from –1.418 to –1.718, and for gastrointestinal problems it increases from –1.518 to –2.434).

However, in all four programmes the standard deviation associated with the distribution of the value for the outcome elasticity increased: for cancer it increased from 0.099 to 0.379; for circulatory disease it increased from 0.228 to 0.843; for respiratory disease it increased from 0.636 to 1.098; and for gastrointestinal disease it increased from 0.468 to 3.834.

Analysis of programme budgeting expenditure for 2007/8 and mortality data for 2007/8/9

Outcome and expenditure models were estimated using updated data for expenditure (from 2006/7 to 2007/8) and updated mortality data (from 2006/7/8 to 2007/8/9). Results for the outcome model are shown in *Table 81* and results for the expenditure model are in *Table 82*. First-stage regressions for these IV models can be found in *Tables 97* and *98* in the *Annex*.

Outcome models

Some of the outcome models in *Table 81* contain just two variables: own programme expenditure and a measure of the need for health care. The latter is usually the measure of need as employed by the Department of Health for resource allocation purposes and this incorporates the CARAN formula for acute services. For the respiratory programme we have added the square of this need measure to improve the model fit. In other PBCs we found that the all service measure of need performed poorly and we have replaced or supplemented it with either a more programme-specific measure (e.g. the epilepsy prevalence rate for neurological mortality) or with a better performing proxy for need (e.g. the percentage of residents born outside the EU for maternity/neonate mortality).

Two results are reported for three of the big four programmes. One of these two results uses two instruments and so we report the instrument validity test statistic. We cannot reject the null hypothesis of instrument validity in all three cases. However, there is some evidence of weak instruments (at least in the respiratory and gastrointestinal programmes) but, if we drop one instrument and re-estimate the model, the evidence of instrument weakness disappears (but of course there is no instrument validity test statistic with this re-estimation). The removal of one instrument has little impact on the coefficient on expenditure and it is this coefficient from this one instrument model that we use below in our cost of a life-year calculations.

The first seven results in *Table 81* show the outcome model for the big four programmes (i.e. for cancer, circulatory disease, respiratory problems and gastrointestinal problems). In all four programmes the need variable has a positive and significant effect on mortality, and expenditure has the anticipated negative effect. The diagnostic statistics reveal that, in all four PBCs, own programme expenditure is endogenous

TABLE 81 Table showing outcome models using spend data for 2007/8 (two MFFs) and mortality data for 2007/8/9

	PBC 2, cancer, 2007/8, outcome model, instrument spend, weighted, second stage		PBC 10, circulation, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 11, respiratory, 2007/8, outcome model, instrument spend, weighted, second stage	
Variable	(1)	(2)	(3)	(4)	(5)
Own programme spend per head	−0.365***	−0.365***	−1.277***	−2.205***	−2.211***
	[0.106]	[0.107]	[0.206]	[0.705]	[0.739]
Need CARAN per head	0.984***	0.985***	2.818***	5.119***	5.113***
	[0.108]	[0.110]	[0.256]	[1.052]	[1.105]
Need CARAN per head squared				4.085**	3.982**
				[1.721]	[1.774]
IMD2007					
Diabetes prevalence rate 2007/8					
Epilepsy prevalence rate 2007/8					
Lone parent households					
HIV need per head squared					
HIV need per head					
Born outside the EU					
No qualifications aged 16–74 years					
No car households					
Full-time students					
Constant	6.635***	6.637***	10.643***	12.244***	12.269***
	[0.480]	[0.483]	[0.996]	[2.947]	[3.090]
Observations	151	151	151	151	151
Endogeneity test statistic	17.288	16.323	39.948	21.368	28.333

PBC 13, gastrointestinal, 2007/8, outcome model, instrument spend, weighted, second stage		PBC 4, endocrine, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 7, neurological, 2007/8, outcome model, other programme need exogenous, weighted, OLS	PBC 17, genitourinary, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 1, infectious diseases, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 18 + 19, maternity and neonates, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 16, trauma and injuries, 2007/8, outcome model, instrument spend, weighted, second stage
(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
−1.292***	−1.328**	−0.566	−0.339**	−1.898**	−0.546*	−0.110	−0.369
[0.497]	[0.519]	[0.550]	[0.144]	[0.921]	[0.300]	[0.139]	[0.353]
3.908***	3.947***		0.853**				3.029***
[0.633]	[0.658]		[0.344]				[0.717]
		0.517***			0.481***		
		[0.109]			[0.098]		
		0.820**					
		[0.359]					
			0.652***				
			[0.231]				
				1.767***			
				[0.430]			
					0.143**		
					[0.064]		
					0.487***		
					[0.120]		
						0.152***	
						[0.028]	
						0.990***	
						[0.115]	
							−0.658***
							[0.221]
							0.528***
							[0.128]
8.688***	8.845***	0.512	3.072***	12.110**	2.176***	3.303***	2.654**
[2.142]	[2.237]	[1.349]	[0.614]	[4.852]	[0.675]	[0.762]	[1.346]
151	151	151	151	147	151	151	151
18.871	17.769	1.293		3.916	3.603	0.551	1.375

TABLE 81 Table showing outcome models using spend data for 2007/8 (two MFFs) and mortality data for 2007/8/9 (*continued*)

	PBC 2, cancer, 2007/8, outcome model, instrument spend, weighted, second stage		PBC 10, circulation, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 11, respiratory, 2007/8, outcome model, instrument spend, weighted, second stage	
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Endogeneity *p*-value	3.21e-05	5.34e-05	1.42e-05	3.79e-06	1.02e-07
Hansen–Sargan test statistic	0.00124	n/a	0.056	n/a	0.163
Hansen-Sargan *p*-value	0.972		0.814		0.686
Shea's partial R^2	0.162	0.162	0.323	0.0832	0.0977
Kleibergen–Paap LM test statistic	19.52	19.44	20.71	8.807	8.840
Kleibergen–Paap *p*-value	5.76e-05	1.04e-05	0.0000	0.00300	0.0120
Kleibergen–Paap *F*-statistic	14.50	29.13	34.54	12.26	6.533
Pesaran–Taylor/ Ramsey test statistic	0.00606	0.0115	2.06	2.839	2.850
Pesaran–Taylor/ Ramsey *p*-value	0.938	0.915	0.1515	0.0920	0.0914

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; n/a, not applicable.
Robust standard errors in brackets.
The addition of unpaid carers as an instrument for the endocrine outcome model generates a Hansen–Sargen test statistic of 0.372 (*p*-value 0.5418) and the coefficient on expenditure is –0.423.

PBC 13, gastrointestinal, 2007/8, outcome model, instrument spend, weighted, second stage		PBC 4, endocrine, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 7, neurological, 2007/8, outcome model, other programme need exogenous, weighted, OLS	PBC 17, genitourinary, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 1, infectious diseases, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 18 + 19, maternity and neonates, 2007/8, outcome model, instrument spend, weighted, second stage	PBC 16, trauma and injuries, 2007/8, outcome model, instrument spend, weighted, second stage
(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1.40e-05	2.49e-05	0.255		0.0478	0.0577	0.458	0.241
0.120	n/a	n/a		6.710	0.583	0.675	5.001
0.729				0.0349	0.747	0.411	0.0820
0.126	0.112	0.133		0.160	0.104	0.201	0.137
10.76	10.53	20.71		20.01	16.45	30.58	16.82
0.00462	0.00117	5.36e-06		0.000169	0.000917	2.29e-07	0.000770
7.809	14.70	25.56		9.624	9.688	23.31	7.835
0.418	0.106	0.00725	0.469	0.393	2.251	0.00684	0.0128
0.518	0.744	0.932	0.704	0.531	0.134	0.934	0.910

TABLE 82 Table showing expenditure models using spend data for 2007/8 (two MFFs) and mortality data for 2007/8/9

Variable	(1) PBC 2, cancer, 2007/8, spend model, second stage	(2) PBC 10, circulation, 2007/8, spend model, second stage	(3) PBC 11, respiratory, 2007/8, spend, model, second stage	(4) PBC 13, gastrointestinal, 2007/8, spend model, second stage	(5) PBC 1, infectious disease, 2007/8, spend model, OLS
All-cause SYLLR excluding cancer	−1.227***				
	[0.220]				
PCT budget per head	0.890**	0.293	0.536*	0.622*	1.435***
	[0.431]	[0.350]	[0.298]	[0.321]	[0.258]
Need CARAN per head	1.659***	3.117***	1.786***	1.982***	
	[0.430]	[0.535]	[0.334]	[0.422]	
All-cause SYLLR excluding circulatory		−2.115***			
		[0.397]			
All-cause SYLLR excluding respiratory			−0.781***		
			[0.236]		
Need CARAN per head squared			1.687***		
			[0.446]		
All-cause SYLLR excluding gastrointestinal				−1.279***	
				[0.333]	
HIV need per head					0.440***
					[0.025]
All-cause SYLLR excluding infectious diseases					−0.543**
					[0.249]
HIV need per head squared					0.183***
					[0.021]
All-cause SYLLR excluding diabetes					
Diabetes prevalence rate 2007/8					
All-cause SYLLR excluding epilepsy					
Epilepsy prevalence rate 2007/8					
All-cause SYLLR excluding renal					
Maternity need per head					
All-cause SYLLR					

(6) PBC 4, endocrine, 2007/8, spend model, second stage	(7) PBC 7, neurological, 2007/8, spend model, second stage	(8) PBC 17, genitourinary, 2007/8, spend model, OLS	(9) PBC 18 + 19, maternity and neonates, 2007/8, spend model, OLS	(10) PBC 23, GMS/PMS, etc., 2007/8, spend model, second stage	(11) PBC 16, trauma and injuries, 2007/8, spend model, second stage
0.264	1.036***	1.004***	0.514*	0.563	1.686***
[0.206]	[0.307]	[0.356]	[0.264]	[0.344]	[0.384]
0.925***		0.029			
[0.305]		[0.371]			
−0.384*					
[0.218]					
0.332***					
[0.123]					
	−0.259				
	[0.223]				
	0.571***				
	[0.072]				
		−0.072			
		[0.168]			
			0.582***		
			[0.098]		
			0.286	−0.169	−0.277
			[0.193]	[0.290]	[0.363]

TABLE 82 Table showing expenditure models using spend data for 2007/8 (two MFFs) and mortality data for 2007/8/9 (*continued*)

Variable	(1) PBC 2, cancer, 2007/8, spend model, second stage	(2) PBC 10, circulation, 2007/8, spend model, second stage	(3) PBC 11, respiratory, 2007/8, spend, model, second stage	(4) PBC 13, gastrointestinal, 2007/8, spend model, second stage	(5) PBC 1, infectious disease, 2007/8, spend model, OLS
Lone pensioner households					
Population working in agriculture					
Constant	4.973	15.081***	4.986**	7.488***	–4.212***
	[3.047]	[3.303]	[2.342]	[2.786]	[1.034]
Observations	151	151	151	151	151
Endogeneity test statistic	20.985	19.454	11.612	15.477	
Endogeneity *p*-value	4.63e-06	1.03e-05	0.000655	8.35e-05	
Hansen–Sargan test statistic	0.411	0.003	1.369	0.0201	
Hansen–Sargan *p*-value	0.522	0.959	0.504	0.887	
Shea's partial R^2	0.384	0.253	0.398	0.325	
Kleibergen–Paap LM test statistic	40.04	28.14	39.41	33.23	
Kleibergen–Paap *p*-value	2.02e-09	7.76e-07	1.42e-08	6.09e-08	
Kleibergen–Paap *F*-statistic	51.44	29.097	40.69	20.04	
Pesaran–Taylor/ Ramsey test statistic	2.262	0.0002	0.0236	0.0341	0.721
Pesaran–Taylor/ Ramsey *p*-value	0.133	0.988	0.878	0.854	0.541

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.

(6) PBC 4, endocrine, 2007/8, spend model, second stage	(7) PBC 7, neurological, 2007/8, spend model, second stage	(8) PBC 17, genitourinary, 2007/8, spend model, OLS	(9) PBC 18 + 19, maternity and neonates, 2007/8, spend model, OLS	(10) PBC 23, GMS/PMS, etc., 2007/8, spend model, second stage	(11) PBC 16, trauma and injuries, 2007/8, spend model, second stage
				−0.480***	
				[0.182]	
					0.132***
					[0.022]
3.555*	−1.684	−2.675	−1.222	1.413	−5.960***
[1.817]	[1.130]	[2.562]	[1.388]	[1.373]	[1.104]
151	151	151	151	151	151
2.846	4.958			0.060	1.769
0.0916	0.0260			0.807	0.183
0.510	2.748			1.091	1.121
0.775	0.0974			0.296	0.571
0.402	0.518			0.416	0.364
40.29	31.53			16.51	27.19
9.26e-09	1.42e-07			0.000260	5.37e-06
37.14	73.21			26.60	32.54
2.351	0.619	1.297	1.018	1.757	0.193
0.125	0.432	0.278	0.387	0.185	0.660

and that the instruments are valid. They also suggest that the instruments are relevant and there is no evidence that the instruments are weak in the models with one excluded instrument. The Pesaran–Taylor test suggests that there is no evidence of model misspecification.

The outcome results for the other programmes [see columns (8)–(13) in *Table 81*] are similar to but more diverse than those for the big four programmes. This is to be anticipated because mortality is a much rarer outcome in these programmes than it is in the big four programmes. Own programme expenditure is not endogenous in four of these programmes but we retain the IV estimator for three of these four because this yields more plausible results than the OLS estimator (the results are more plausible in the sense that the signs on the coefficients are more in line with our prior expectations).

Expenditure has the anticipated negative effect on mortality in the endocrine problems programme but this is not statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that the diabetes prevalence rate is positively associated with mortality, as is a measure of deprivation (the IMD2007).

Mortality from epilepsy is negatively and significantly associated with expenditure in the neurological programme. Both the all service need for health care and the epilepsy prevalence rate are positively and significantly associated with mortality in this programme.

Expenditure has a negative and statistically significant effect on mortality (from renal problems) in the genitourinary problems programme. The prevalence of lone parent households is positively associated with mortality.

Expenditure has the anticipated negative effect on mortality in the infectious disease programme and this is statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that a measure of need associated with HIV is positively associated with mortality, as is a measure of deprivation (the IMD2007).

Expenditure has the anticipated negative effect on mortality in the maternity and neonates programme, but the estimated coefficient is not statistically significant. In this PBC the generic all service measure of need has been replaced with two other indicators of deprivation – the proportion of residents born outside the EU and the proportion of those aged 16–74 years without any qualifications – and both of these are positively associated with mortality.

Finally, expenditure and need have the anticipated effects on mortality in the trauma and injuries programme. In addition, the proportion of households without access to a car is negatively associated with mortality from fractures (perhaps access to a car facilitates involvement in serious road traffic accidents), and the proportion of residents that are students is positively associated with mortality from fractures.

The relevant statistical test suggests that expenditure is endogenous in 6 of the 10 programmes but we have retained the IV estimates for three of the other four programmes because they provide plausible results. The Hansen–Sargen test suggests that the selected instruments are valid, and the Kleibergen–Paap LM statistic suggests that they are relevant (i.e. correlated with the endogenous regressor). With the possible exception of the trauma and injuries programme, the Kleibergen–Paap *F*-statistic suggests that we do not have a problem with weak instruments.[ai] Finally, the Pesaran–Taylor/Ramsey reset test statistics reveal no evidence of misspecification.

Expenditure models

Most of the expenditure models in *Table 82* contain just three variables: the PCT budget, a proxy for the own programme need for health care, and a proxy for the need for health care in other programmes.

The budget term is positive in all 11 models and it is statistically significant in 8 of these 11 models.

The usual proxy for the own programme need for health care (i.e. the all service measure of need) is present in six of the models and it is significant in five of them. Its presence is supplemented with the addition of its squared value to improve model fit in the respiratory problems programme.

In some programmes (e.g. endocrine, metabolic and nutritional, and neurological), we have replaced and/or supplemented the all service measure of need with a more programme-specific measure (e.g. the diabetes prevalence rate and the epilepsy prevalence rate) and these measures of need have the anticipated positive impact on expenditure.

In addition, in a couple of other programmes we have used alternative proxies for the own programme need (e.g. with the use of the Department of Health's measure of maternity need in the maternity and neonates expenditure equation).

For 8 of the 11 programmes we have used the all-cause mortality rate less the own programme mortality rate as the proxy for the need for health care in other programmes, and the coefficient on this term is negative in seven programmes and statistically significant in six of the seven. In three programmes – maternity and neonates, GMS/PMS, and trauma and injuries programmes – we have used the all-cause mortality rate as the proxy for the need for health care in other programmes due to difficulties associated with the measurement of the own programme mortality rate. The coefficient on this term is not significant in any of the three models.

The relevant statistical test suggests that expenditure is endogenous in 6 of the 11 programmes, but we have retained the IV estimates for two other programmes (GMS/PMS, and trauma and injuries) because the IV estimator provides more plausible results. In the other three programmes we report OLS results.

The Hansen–Sargen test suggests that the selected instruments are valid, and the Kleibergen–Paap LM statistic suggests that they are relevant (i.e. correlated with the endogenous regressor). The Kleibergen–Paap *F*-statistic suggests that we do not have a problem with weak instruments. Finally, the Pesaran–Taylor reset test statistics and the Ramsey reset *F*-statistics reveal no evidence of model misspecification.

Calculation of the cost of a life and life-year

Expenditure and outcome elasticities for our preferred models are shown in *Table 83* [see columns (D) and (G)] and these are used to calculate the cost of a life and the cost of a life-year, both for individual programmes and for all programmes collectively.

Column (L) (see *Table 83*) reports the cost per life gained and column (R) (see *Table 83*) reports the cost per YLG. From the latter we can see that the cost per YLG is £13,830 for the big four programmes and £28,983 for all 10 programmes with a mortality-based outcome indicator. These represent 30% and 45% increases on the respective costs for the previous year (i.e. using expenditure data for 2006/7 and mortality data for 2006/7/8).

If we assume that the other 13 programmes (all without a mortality-based outcome indicator) offer no health gain, then the cost per life-year across all PCT expenditure is £82,765. This is up from £73,457 using data for the previous year (an increase of 13%).

In addition, *Table 84* shows that if we assume that PBC 23 generates a zero health gain and that the gain attributable to the remaining 12 programmes is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes is £31,846 (it was £22,565 using data for the previous year).

TABLE 83 Table showing cost of life and life-year estimates using spend data for 2007/8 and outcome data for 2007/8/9 (assumes zero health gain for 13 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2007/8	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2007/8/9	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
1	Cancer	4573	0.890	40.70	61,960	0.365	201.28	202,207
2	Circulatory problems	6325	0.293	18.53	39,304	1.277	147.06	126,018
3	Respiratory problems	3431	0.536	18.39	10,764	2.205	127.22	144,557
4	Gastrointestinal problems	3805	0.622	23.67	6031	1.328	49.82	475,081
Big four programmes summary								
5	Spend 2007 and mortality 2007/8/9	18,134		101.29	118,059		525.37	192,795
6	Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801		665.10	137,188
7	Spend 2006 and mortality 2004/5/6	17,268		114.04	125,290		953.13	119,650
8	Spend 2005 and mortality 2002/3/4	17,625		141.22	125,290		909.96	155,196
9	Infectious diseases	1119	1.436	16.07	1977	0.548	15.56	1,032,863
10	Endocrine problems	1997	0.264	5.27	1471	0.566	2.20	2,398,551
11	Neurological problems	3165	1.035	32.76	718	0.339	2.52	13,003,180
12	Genitourinary problems	3439	1.004	34.53	270	1.855	5.03	6,866,327
13	Trauma and injuries	2918	1.686	49.20	1013	0.369	6.30	7,806,376
14	Maternity and neonates	3662	0.514	18.82	2199	0.110	1.24	15,139,113
Other six programmes summary								
15	Spend 2007 and mortality 2007/8/9	16,300		156.65	7648		32.85	4,768,699
16	Spend 2006 and mortality 2006/7/8	15,643		93.29	7839		16.14	5,780,723
17	Spend 2006 and mortality 2004/5/6	15,643		112.13	7923		18.17	6,172,491
18	Spend 2005 and mortality 2002/3/4	12,743		99.44	7923		16.26	6,115,621

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2007/09	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
0.984	204.55	198,972	2,189,685	2371	0.984	2410	17,165	16,891
0.992	148.25	125,010	1,313,223	1638	0.992	1651	11,315	11,224
0.773	164.58	111,742	315,457	1243	0.773	1608	14,798	11,439
0.571	87.25	271,271	343,355	945	0.571	1656	25,034	14,295
	604.62	167,526	4,161,720	6197		7324	16,345	13,830
	761.49	119,823	4,238,786	7399		8604	12,333	10,604
			4,335,559	10,576			10,783	
			4,516,953	10,986			12,855	
1.000	15.56	1,032,863	106,092	278	1.000	278	57,742	57,742
0.634	3.47	1,520,681	55,492	28	0.634	44	190,745	120,932
0.136	18.52	1,768,432	64,873	76	0.136	558	431,749	58,718
0.172	29.24	1,181,008	8529	53	0.172	308	652,096	112,160
0.175	36.01	1,366,116	21,273	44	0.175	252	1,115,197	195,159
8.213	0.15	124,337,534	489,170	92	0.679	136	204,168	138,630
	102.95	1,521,610	745,429	571		1575	274,309	99,428
	25.05	3,724,129	762,991	362		639	258,046	146,108
			757,531	249			449,706	
			751,009	337			295,074	

TABLE 83 Table showing cost of life and life-year estimates using spend data for 2007/8 and outcome data for 2007/8/9 (assumes zero health gain for 13 programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2007/8	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2007/8/9	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
All 10 programmes summary								
19	Spend 2007 and mortality 2007/8/9	34,434		257.94	125,707		558.22	462,067
20	Spend 2006 and mortality 2006/7/8	32,911		184.53	128,640		681.24	270,881
21	Spend 2006 and mortality 2004/5/6	32,911		226.18	133,213		971.30	232,861
22	Spend 2005 and mortality 2002/3/4	30,368		240.67	133,213		926.22	259,838
Assume zero health gain in the other 13 programmes: other 13 programmes summary								
23	Spend 2007 and mortality 2007/8/9	39,223		478.63			0.00	
24	Spend 2006 and mortality 2006/7/8	34,985		494.43			0.00	
25	Spend 2006 and mortality 2004/5/6	34,985		452.78			0.00	
26	Spend 2005 and mortality 2002/3/4	33,942		402.43			0.00	
All 23 programmes								
27	Spend 2007 and mortality 2007/8/9	73,657		736.57			558.22	1,319,496
28	Spend 2006 and mortality 2006/7/8	67,896		678.96			681.24	996,655
29	Spend 2006 and mortality 2004/5/6	67,896		678.96			971.30	699,024
30	Spend 2005 and mortality 2002/3/4	64,310		643.10			926.22	694,330

Note

All 23 programmes spend: 2007/8 £73,657; 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2007/8 1.00%; 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2007/8 0.01; 2006/7 0.01; 2005/6 0.01.
Change in budget: 2007/8 £736.57; 2006/7 £678.96; 2005/6 £643.10.
The YLL for maternity and neonates is estimated as [(6456 neonate deaths × 75 years) + (142 maternal deaths × 35 years)]. This totals 489,170 life-years.
The annual mortality figures reported in cells F7 and F8, and F17 and F18 are identical because we do not have mortality data for 2002/3/4.
For expenditure in 2007/8, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.
The adjustment for the coverage of the mortality and YLL data relative to the spend data uses deaths under age 75 years in England in 2008.
The YLL figure for trauma and injuries has been estimated assuming that each death is on average at age 67 years so that, on average, 7 years of life are lost per death.

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2007/09	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
	707.57	364,540	4,907,149	6768		8900	38,110	28,983
	786.54	234,617	5,001,777	7760		9243	23,780	19,965
			5,093,090	10,826			20,893	
			5,267,962	11,322			21,256	
	0.00			0.00		0.00		
				0.00		0.00		
				0.00				
				0.00				
	707.57	1,040,992		6768		8900	108,829	82,765
	786.54	863,228		7760		9243	87,494	73,457
				10,826			62,718	
				11,322			56,799	

TABLE 84 Table showing cost of life and life-year estimates using spend data for 2007/8 and outcome data for 2007/8/9 (assumes zero health gain for PBC 23 and 'average' gain for other 12 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2007/8	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2007/8/9	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
1	Cancer	4573	0.890	40.70	61,960	0.365	201.28	202,207
2	Circulatory problems	6325	0.293	18.53	39,304	1.277	147.06	126,018
3	Respiratory problems	3431	0.536	18.39	10,764	2.205	127.22	144,557
4	Gastrointestinal problems	3805	0.622	23.67	6031	1.328	49.82	475,081
Big four programmes summary								
5	Spend 2007 and mortality 2007/8/9	18,134		101.29	118,059		525.37	192,795
6	Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801		665.10	137,188
7	Spend 2006 and mortality 2004/5/6	17,268		114.04	125,290		953.13	119,650
8	Spend 2005 and mortality 2002/3/4	17,625		141.22	125,290		909.96	155,196
9	Infectious diseases	1119	1.436	16.07	1977	0.548	15.56	1,032,863
10	Endocrine problems	1997	0.264	5.27	1471	0.566	2.20	2,398,551
11	Neurological problems	3165	1.035	32.76	718	0.339	2.52	13,003,180
12	Genitourinary problems	3439	1.004	34.53	270	1.855	5.03	6,866,327
13	Trauma and injuries	2918	1.686	49.20	1013	0.369	6.30	7,806,376
14	Maternity and neonates	3662	0.514	18.82	2199	0.110	1.24	15,139,113
Other six programmes summary								
15	Spend 2007 and mortality 2007/8/9	16,300		156.65	7648		32.85	4,768,699
16	Spend 2006 and mortality 2006/7/8	15,643		93.29	7839		16.14	5,780,723
17	Spend 2006 and mortality 2004/5/6	15,643		112.13	7923		18.17	6,172,491
18	Spend 2005 and mortality 2002/3/4	12,743		99.44	7923		16.26	6,115,621

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2007/8/9	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
0.984	204.55	198,972	2,189,685	2371	0.984	2410	17,165	16,891
0.992	148.25	125,010	1,313,223	1638	0.992	1651	11,315	11,224
0.773	164.58	111,742	315,457	1243	0.773	1608	14,798	11,439
0.571	87.25	271,271	343,355	945	0.571	1656	25,034	14,295
	604.62	167,526	4,161,720	6197		7324	16,345	13,830
	761.49	119,823	4,238,786	7399		8604	12,333	10,604
			4,335,559	10,576			10,783	
			4,516,953	10,986			12,855	
1.000	15.56	1,032,863	106,092	278	1.000	278	57,742	57,742
0.634	3.47	1,520,681	55,492	28	0.634	44	190,745	120,932
0.136	18.52	1,768,432	64,873	76	0.136	558	431,749	58,718
0.172	29.24	1,181,008	8529	53	0.172	308	652,096	112,160
0.175	36.01	1,366,116	21,273	44	0.175	252	1,115,197	195,159
8.213	0.15	124,337,534	489,170	92	0.679	136	204,168	138,630
	102.95	1,521,610	745,429	571		1575	274,309	99,428
	25.05	3,724,129	762,991	362		639	258,046	146,108
			757,531	249			449,706	
			751,009	337			295,074	

TABLE 84 Table showing cost of life and life-year estimates using spend data for 2007/8 and outcome data for 2007/8/9 (assumes zero health gain for PBC 23 and 'average' gain for other 12 programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2007/8	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2007/8/9	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
All 10 programmes								
19	Spend 2007 and mortality 2007/8/9	34,434		257.94	125,707		558.22	462,067
20	Spend 2006 and mortality 2006/7/8	32,911		184.53	128,640		681.24	270,881
21	Spend 2006 and mortality 2004/5/6	32,911		226.18	133,213		971.30	232,861
22	Spend 2005 and mortality 2002/3/4	30,368		240.67	133,213		926.22	259,838
Other 13 PBCs? Assume zero health gain in PBC 23 ...								
23	PBC 23 spend 2007 and mortality 2007/8/9	11,763	0.563	66.23			0.00	
24	PBC 23 spend 2006 and mortality 2006/7/8	10,585	0.739	78.22			0.00	
25	PBC 23 spend 2006 and mortality 2004/5/6	10,585	0.759	80.34			0.00	
26	PBC 23 spend 2005 and mortality 2002/3/4	8449	0.926	78.24			0.00	
... and that the gain in 10 PBCs (see row 19) applies to the remaining 12 PBCs								
27	12 PBCs spend 2007 and mortality 2007/8/9	27,460		412.41			892.53	462,067
28	12 PBCs spend 2006 and mortality 2006/7/8	24,400		416.20			1536.48	270,881
29	12 PBCs spend 2006 and mortality 2004/5/6	24,400		372.44			1599.42	232,861
30	12 PBCs spend 2005 and mortality 2002/3/4	25,493		324.20			1247.69	259,838

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2007/8/9	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
	707.57	364,540	4,907,149	6768		8900	38,110	28,983
	786.54	234,617	5,001,777	7760		9243	23,780	19,965
			5,093,090	10,826			20,893	
			5,267,962	11,322			21,256	
	0.00			0.00		0.00		
				0.00		0.00		
				0.00				
				0.00				
	1131.31	364,540		10,821		14,229	38,110	28,983
	1773.97	234,617		17,502		20,847	23,780	19,965
				17,826			20,893	
				15,252			21,256	

TABLE 84 Table showing cost of life and life-year estimates using spend data for 2007/8 and outcome data for 2007/8/9 (assumes zero health gain for PBC 23 and 'average' gain for other 12 programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2007/8	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2007/8/9	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
All 23 programmes								
31	23 PBCs spend 2007 and mortality 2007/8/9	73,657		736.57			1450.75	507,717
32	23 PBCs spend 2006 and mortality 2006/7/8	67,896		678.96			2217.72	306,153
33	23 PBCs spend 2006 and mortality 2004/5/6	67,896		678.96			2570.72	264,113
34	23 PBCs spend 2005 and mortality 2002/3/4	64,310		643.10			2173.90	295,827

Note
All 23 programmes spend: 2007/8 £73,657; 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2007/8 1.00%; 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2007/8 0.01; 2006/7 0.01; 2005/6 0.01.
Change in budget: 2007/8 £736.57; 2006/7 £678.96; 2005/6 £643.10.
The annual mortality figures reported in cells F7 and F8, and F17 and F18 are identical because we do not have mortality data for 2002/3/4.
The coverage of the YLL data relative to the spend data for trauma and injuries is assumed to take a value of 1.0 (that is, the ICD-10 coverage is the same).
For expenditure in 2007/8, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.
The adjustment for the coverage of the mortality and YLL data relative to the spend data uses deaths under age 75 years in England in 2008.

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2007/8/9	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
	1838.88	400,554		17,590		23,129	41,875	31,846
	2560.50	265,167		25,262		30,090	26,876	22,565
				28,652			23,697	
				26,575			24,200	

Summary and conclusion

In this section we have estimated outcome and expenditure models using PB data for 2007/8 and mortality data for 2007/8/9. The cost of an additional life-year for all 10 programmes with a mortality-based outcome is £28,983. This is a 45% increase on the cost (£19,965) for the previous year (i.e. using expenditure data for 2006/7 and mortality data for 2006/7/8). The next section presents outcome and expenditure models using PB data for 2008/9 and mortality data for 2008/9/10, and it explores the reasons for the increase in the cost of an additional life-year identified in this section.

Analysis of programme budgeting expenditure for 2008/9 and mortality data for 2008/9/10

Outcome and expenditure models were estimated using updated data for expenditure (from 2007/8 to 2008/9) and updated mortality data (from 2007/8/9 to 2008/9/10). Results for the outcome model are shown in *Table 85* and results for the expenditure model are in *Table 86*. First-stage regressions for these IV models can be found in *Tables 99* and *100* in the *Annex*.

Outcome models

Most of the outcome models in *Table 85* contain just two variables: own programme expenditure and a measure of the need for health care. The latter is usually the measure of need as employed by the Department of Health for resource allocation purposes and this incorporates the CARAN formula for acute services. For the respiratory disease programme we have added the square of the need measure to improve the model fit. In other PBCs (e.g. for the endocrine, metabolic and nutritional programmes), we found that the all service measure of need performed poorly and we have replaced it with a more programme-specific measure (e.g. the diabetes prevalence rate) or with a better performing proxy for need (e.g. the percentage of residents born outside the EU for maternity/neonate mortality).

The relevant statistical test suggests that expenditure is endogenous in 6 of the 10 programmes but we have retained the IV estimates for the other four because they provide plausible results. The Hansen–Sargen test suggests that the selected instruments are valid, and the Kleibergen–Paap LM statistic suggests that they are relevant (i.e. correlated with the endogenous regressor). The Kleibergen–Paap *F*-statistic suggests that we do not have a problem with weak instruments (although the *F*-statistic is marginally less than the conventional target value of 10 in the genitourinary and infectious disease programmes). Finally, the Pesaran–Taylor reset test statistics reveal no evidence of misspecification.

Results for the big four programmes are shown in the first five columns of *Table 85*. Two results are reported for the gastrointestinal programme. The first of these [see *Table 85*, column (4)] uses two instruments and so we report the instrument validity test statistic. However, one of these instruments is insignificant in the first-stage regression and, if we drop this instrument and re-estimate the model, we obtain the result in *Table 85*, column (5) (but of course there is no instrument validity test statistic with this re-estimation). The removal of one instrument has little impact on the coefficient on expenditure but the Kleibergen–Paap *F*-statistic is now much greater than 10.

In all of the big four programmes the need variable has a positive and significant effect on mortality, and expenditure has the anticipated negative effect. As we have noted before, the outcome results for the other programmes [see *Table 85*, columns (6)–(10)] are similar to but more diverse than those for the big four programmes. This is to be anticipated because mortality is a much rarer outcome in these programmes than it is in the big four programmes.

Expenditure has the anticipated negative effect on mortality in the endocrine problems programme and this is statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that the diabetes prevalence rate is positively associated with mortality, as is a measure of deprivation (the IMD2007).

Expenditure has a negative but statistically insignificant impact on mortality from epilepsy in the neurological programme, and the all service indicator of the need for health care is positively and significantly associated with mortality in this programme.

Expenditure also has a negative but not statistically significant effect on mortality (from renal problems) in the genitourinary problems programme. The prevalence of lone parent households is positively associated with mortality.

Expenditure has the anticipated negative effect on mortality in the infectious disease programme and this is statistically significant. The all service measure of need is not relevant for this PBC; instead, we find that a measure of need associated with HIV is positively associated with mortality, as is a measure of deprivation (the IMD2007).

Expenditure has the anticipated negative effect on mortality in the maternity and neonates programme. In this PBC the coefficient on the generic all service measure of need is positive but not significant. It has been supplemented with two other indicators of deprivation – the proportion of residents born outside the EU and the proportion of those aged 16–74 years without any qualifications – and both of these are positively associated with mortality.

Finally, we were unable to develop a plausible outcome model for the trauma and injuries programme.

Expenditure models

Most of the expenditure models in *Table 86* contain just three variables: the PCT budget, a proxy for the own programme need for health care, and a proxy for the need for health care in other programmes.

The budget term is positive and statistically significant in 10 of the 11 models.

The usual proxy for the own programme need for health care (i.e. the all service measure of need) is positive and significant in 5 of the 11 results. In a couple of programmes (respiratory disease and endocrine problems) we have added the squared value of need to improve the model fit and in both cases this term is positive and significant.

In some programmes (e.g. endocrine and neurological), we have replaced and/or supplemented the all service measure of need with a more programme-specific measure (e.g. the diabetes and the epilepsy prevalence rates) and these usually have a positive and significant impact on expenditure.

In addition, in a couple of programmes we have used alternative proxies for own programme need (e.g. with the use of the Department of Health's measure of maternity need in the maternity/neonates expenditure equation and the use of HIV need in the infectious diseases programme).

For 8 of the 11 programmes we have used the all-cause mortality rate less the own programme mortality rate as the proxy for the need for health care in other programmes, and the coefficient on this term is negative in seven programmes and statistically significant in six of the seven. In three programmes – maternity and neonates, GMS/PMS, and trauma and injuries programmes – we have used the all-cause mortality rate as the proxy for the need for health care in other programmes due to difficulties associated with the measurement of the own programme mortality rate. The coefficient on this term is negative but not significant in these three models.

The relevant statistical test suggests that expenditure is endogenous in 5 of the 11 programmes but we have retained the IV estimates for two further programmes (endocrine problems, and maternity and neonates) because the IV estimator provides more plausible results than the OLS estimator. In the other four programmes we report OLS results.

TABLE 85 Table showing outcome models using spend data for 2008/9 (two MFFs) and mortality data for 2008/9/10

Variable	2008/9, outcome model, instrument spend, weighted, second stage			
	(1) PBC 2, cancer	(2) PBC 10, circulation	(3) PBC 11, respiratory	(4) PBC 13, gastrointestinal
Own programme spend per head	−0.307***	−1.319***	−1.808***	−1.287***
	[0.084]	[0.186]	[0.488]	[0.478]
Need CARAN	0.954***	2.840***	4.811***	3.907***
	[0.095]	[0.247]	[0.760]	[0.625]
Need CARAN2			3.016**	
			[1.284]	
Diabetes prevalence rate				
IMD2007				
Lone parent households				
HIV need per head				
HIV need per head squared				
Born outside EU				
Population with no qualifications				
Constant	6.372***	10.861***	10.818***	8.715***
	[0.381]	[0.908]	[2.111]	[2.076]
Observations	151	151	151	151
Endogeneity test statistic	11.547	25.007	30.177	14.839
Endogeneity *p*-value	0.000679	5.71e-07	3.94e-08	0.000117
Hansen–Sargan test statistic	0.843	0.801	0.00285	0.101
Hansen–Sargan *p*-value	0.358	0.371	0.957	0.751
Shea's partial R^2	0.245	0.282	0.176	0.192
Kleibergen–Paap LM test statistic	23.51	24.85	13.79	13.60
Kleibergen–Paap *p*-value	7.85e-06	4.02e-06	0.00101	0.00111
Kleibergen–Paap *F*-statistic	21.14	47.87	15.10	11.93
Pesaran–Taylor reset statistic	0.416	0.405	0.104	0.483
Pesaran–Taylor *p*-value	0.519	0.524	0.747	0.487

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.

(5) PBC 13, gastrointestinal	(6) PBC 4, endocrine	(7) PBC 7, neurological	(8) PBC 17, genitourinary	(9) PBC 1, infectious disease	(10) PBC 18 + 19, maternity and neonates
−1.364**	−1.170***	−0.417	−1.615	−0.504**	−0.125
[0.549]	[0.431]	[0.473]	[1.608]	[0.223]	[0.188]
3.993***		1.280**			0.405
[0.700]		[0.579]			[0.288]
	0.903**				
	[0.371]				
	0.711***			0.528***	
	[0.108]			[0.091]	
			1.820***		
			[0.659]		
				0.468***	
				[0.093]	
				0.163***	
				[0.046]	
					0.169***
					[0.031]
					0.752***
					[0.129]
9.048***	2.107**	3.233	11.065	1.844***	3.097***
[2.386]	[1.022]	[1.987]	[8.588]	[0.500]	[0.949]
151	151	151	148	151	151
11.963	6.209	2.251	0.530	2.952	0.340
0.000543	0.0127	0.133	0.467	0.0858	0.560
	0.558	4.446	3.513	4.412	0.225
	0.757	0.108	0.0609	0.220	0.635
0.150	0.193	0.155	0.103	0.191	0.263
11.64	25.23	21.85	12.51	20.29	22.02
0.000644	1.38e-05	7.02e-05	0.00192	0.000437	1.65e-05
16.51	13.56	20.13	9.000	9.306	16.92
0.0584	1.211	0.838	1.681	0.0456	0.107
0.809	0.271	0.360	0.195	0.831	0.744

TABLE 86 Table showing expenditure models using spend data for 2008/9 (two MFFs) and mortality data for 2008/9/10

Variable	(1) PBC 2, cancer, 2008/9, spend model, instrument other programme need, weighted, second stage	(2) PBC 10, circulatory, 2008/9, spend model, instrument other programme need, weighted, second stage	(3) PBC 11, respiratory, 2008/9, spend model, instrument other programme need, weighted, second stage	(4) PBC 13, gastrointestinal, 2008/9, spend model, instrument other programme need, weighted, second stage	(5) PBC 1, infectious disease, 2008/9, spend model, other programme need exogenous, weighted, OLS
All-cause SYLLR excluding cancer	−1.216***				
	[0.186]				
PCT budget per head	0.525*	0.648	0.652*	0.456*	1.546***
	[0.296]	[0.552]	[0.337]	[0.254]	[0.265]
Need CARAN per head	2.081***	2.606***	2.036***	2.095***	
	[0.389]	[0.623]	[0.377]	[0.411]	
All-cause SYLLR excluding circulatory		−1.987***			
		[0.351]			
All-cause SYLLR excluding respiratory			−1.081***		
			[0.264]		
Need CARAN per head squared			1.336***		
			[0.501]		
All-cause SYLLR excluding gastrointestinal				−1.256***	
				[0.317]	
HIV need per head					0.456***
					[0.027]
All-cause SYLLR excluding infectious disease					−0.472**
					[0.227]
HIV need per head squared					0.178***
					[0.023]
All-cause SYLLR excluding diabetes					
Diabetes prevalence rate					
All-cause SYLLR excluding epilepsy					
Epilepsy prevalence rate					

(6) PBC 4, endocrine, 2008/9, spend model, instrument other programme need, weighted, second stage	(7) PBC 7, neurological, 2008/9, spend model, instrument other programme need, weighted, second stage	(8) PBC 17, genitourinary, 2008/9, spend model, other programme need exogenous, weighted, OLS	(9) PBC 18 + 19, maternity and neonates, 2008/9, spend model, instrument other programme need, weighted, second stage	(10) PBC 23a, GMS/PMS, 2008/9, spend model, other programme need exogenous, weighted, OLS	(11) PBC 16, trauma and injuries, 2008/9, spend model, other programme need exogenous, weighted, OLS
0.484**	0.980***	0.697***	0.975***	0.494***	1.344***
[0.240]	[0.220]	[0.209]	[0.303]	[0.140]	[0.236]
0.553		0.295		0.724**	
[0.369]		[0.310]		[0.334]	
1.602***					
[0.495]					
–0.164					
[0.197]					
0.439***					
[0.112]					
	–0.257*				
	[0.153]				
	0.414***				
	[0.063]				

TABLE 86 Table showing expenditure models using spend data for 2008/9 (two MFFs) and mortality data for 2008/9/10 (*continued*)

Variable	(1) PBC 2, cancer, 2008/9, spend model, instrument other programme need, weighted, second stage	(2) PBC 10, circulatory, 2008/9, spend model, instrument other programme need, weighted, second stage	(3) PBC 11, respiratory, 2008/9, spend model, instrument other programme need, weighted, second stage	(4) PBC 13, gastrointestinal, 2008/9, spend model, instrument other programme need, weighted, second stage	(5) PBC 1, infectious disease, 2008/9, spend model, other programme need exogenous, weighted, OLS
Born outside EU					
All-cause SYLLR excluding renal					
All-cause SYLLR					
Maternity need per head					
Lone pensioner households					
Permanently sick aged 16–74 years					
Professional occupations					
Working in agriculture					
Constant	7.556***	11.702***	6.044**	8.551***	–5.471***
	[2.406]	[4.445]	[2.651]	[2.592]	[1.096]
Observations	151	151	151	151	151
R^2					0.776
Endogeneity test statistic	17.101	22.697	17.212	12.023	
Endogeneity *p*-value	3.54e-05	1.90e-06	3.34e-05	0.000525	
Hansen–Sargan test statistic	0.0538	0.332	0.858	0.420	
Hansen–Sargan *p*-value	0.817	0.565	0.354	0.517	
Shea's partial R^2	0.379	0.265	0.389	0.331	
Kleibergen–Paap LM statistic	39.01	29.71	37.32	33.84	
Kleibergen–Paap *p*-value	3.38e-09	3.54e-07	7.87e-09	4.48e-08	

(6) PBC 4, endocrine, 2008/9, spend model, instrument other programme need, weighted, second stage	(7) PBC 7, neurological, 2008/9, spend model, instrument other programme need, weighted, second stage	(8) PBC 17, genitourinary, 2008/9, spend model, other programme need exogenous, weighted, OLS	(9) PBC 18 + 19, maternity and neonates, 2008/9, spend model, instrument other programme need, weighted, second stage	(10) PBC 23a, GMS/PMS, 2008/9, spend model, other programme need exogenous, weighted, OLS	(11) PBC 16, trauma and injuries, 2008/9, spend model, other programme need exogenous, weighted, OLS
		0.039***			
		[0.014]			
		−0.029			
		[0.139]			
			−0.348	−0.106	−0.269
			[0.302]	[0.104]	[0.195]
			0.846***		
			[0.120]		
				−0.166**	
				[0.079]	
				−0.310***	
				[0.092]	
				−0.124*	
				[0.064]	
					0.107***
					[0.022]
0.488	−1.315	−0.521	−0.696	0.586	−3.605***
[2.282]	[1.005]	[1.857]	[0.800]	[1.133]	[1.027]
151	151	151	151	150	151
		0.497		0.278	0.339
1.803	7.163		3.243		
0.179	0.00744		0.0717		
0.138	0.594		1.349		
0.710	0.441		0.509		
0.399	0.500		0.257		
38.45	35.08		22.81		
4.48e-09	2.41e-08		4.43e-05		

TABLE 86 Table showing expenditure models using spend data for 2008/9 (two MFFs) and mortality data for 2008/9/10 (*continued*)

Variable	(1) PBC 2, cancer, 2008/9, spend model, instrument other programme need, weighted, second stage	(2) PBC 10, circulatory, 2008/9, spend model, instrument other programme need, weighted, second stage	(3) PBC 11, respiratory, 2008/9, spend model, instrument other programme need, weighted, second stage	(4) PBC 13, gastrointestinal, 2008/9, spend model, instrument other programme need, weighted, second stage	(5) PBC 1, infectious disease, 2008/9, spend model, other programme need exogenous, weighted, OLS
Kleibergen–Paap *F*-statistic	39.97	26.93	44.98	20.13	
Pesaran–Taylor reset statistic	1.129	0.0810	0.000203	0.557	
Pesaran–Taylor *p*-value	0.288	0.776	0.989	0.456	
Ramsey reset *F*-statistic					1.723
Probability > *F*					0.165

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.

(6) PBC 4, endocrine, 2008/9, spend model, instrument other programme need, weighted, second stage	(7) PBC 7, neurological, 2008/9, spend model, instrument other programme need, weighted, second stage	(8) PBC 17, genitourinary, 2008/9, spend model, other programme need exogenous, weighted, OLS	(9) PBC 18 + 19, maternity and neonates, 2008/9, spend model, instrument other programme need, weighted, second stage	(10) PBC 23a, GMS/PMS, 2008/9, spend model, other programme need exogenous, weighted, OLS	(11) PBC 16, trauma and injuries, 2008/9, spend model, other programme need exogenous, weighted, OLS
47.20	75.67		16.35		
0.354	0.366		0.00412		
0.552	0.545		0.949		
		1.431		0.072	1.044
		0.236		0.975	0.375

The Hansen–Sargen test suggests that the selected instruments are valid, and the Kleibergen–Paap LM statistic suggests that they are relevant (i.e. correlated with the endogenous regressor). The Kleibergen–Paap *F*-statistic suggests that we do not have a problem with weak instruments. Finally, the Pesaran–Taylor reset test statistics and the Ramsey reset *F*-statistics reveal no evidence of model misspecification.

Calculation of the cost of a life and life-year

Expenditure and outcome elasticities for our preferred models are shown in *Table 87* [see columns (D) and (G)] and these are used to calculate the cost of a life and the cost of a life-year, both for individual programmes and for all programmes collectively.

Again, *Table 87*, column (L) reports the cost per life gained and column (R) reports the cost per YLG. From the latter we can see that the cost per YLG has increased slightly compared with that using the previous expenditure and mortality data set (i.e. for 2007 and 2007/8/9, respectively): it has increased from £13,830 to £14,650 for the big four programmes and from £28,983 to £30,883 for all 10 programmes with a mortality-based outcome indicator.

If we assume that the other 13 programmes offer no health gain, then the cost per life-year across all PCT expenditure has increased from £82,765 in 2007/8 to £84,974 in 2008/9.

In addition, *Table 88* shows that if we assume that PBC 23 generates a zero health gain and that the gain attributable to the remaining 12 programmes is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes in 2008/9 is £33,333. This is a 5% increase on the figure (£31,846) for the previous year.

Comparing the cost of life-year estimates associated with different data sets

Table 89 presents expenditure and outcome elasticities for the five combinations of expenditure and outcome data that have been used to estimate our model. It also reports the corresponding unadjusted cost of life-year estimates (i.e. estimates that are unadjusted for the mismatch in the ICD-10 coverage of the expenditure and mortality data). It is clear from *Table 89* [see row (13)] that the (unadjusted) cost of a life-year for the 10 programmes with a mortality-based outcome indicator fluctuated around £22,000 for the first three sets of estimations [see columns *Table 89*, (M)–(O)]. However, using the two most recent sets of expenditure data (i.e. for 2007/8 and then for 2008/9), the figures in the table suggest that this cost has increased to about £38,000.

What are the proximate causes of this increase? Recall that the cost of a life-year is calculated as:

$$\frac{\text{The change in expenditure associated with a 1\% budget increase}}{\text{The change in the number of life-years lost associated with this increase}}$$

For 2006/7 (using mortality data for 2006/7/8) and for the 10 programmes with a mortality-based outcome indicator, the change in expenditure associated with a 1% budget increase is £184.53M and the change in the number of life-years lost associated with this increase is 7760 (see *Table 67* for the calculation of these figures). Thus, the cost of a life-year is £23,780 (= £184.53M/7760).

For 2007/8 (using mortality data for 2007/8/9) and for the 10 programmes with a mortality-based outcome indicator, the change in expenditure associated with a 1% budget increase is £257.94M and the change in the number of life-years lost associated with this increase is 6768 (see *Table 83* in the appendix for the calculation of these figures). Thus, the cost of a life-year is £38,110 (= £257.94M/6768).

It is clear that the 60% increase in the cost of a life-year between 2006/7 and 2007/8 is largely attributable to (a) the 40% increase in the additional expenditure (up from £184.53M to £257.94M) directed towards these 10 programmes following a 1% budget increase; and (b) the 12% decline in the number of YLGs associated with this increase in expenditure (down from 7760 to 6768 life-years).

The rise in the share of the budget increase directed towards these programmes can be attributed to the increase in the implied expenditure elasticity associated with these 10 programmes (up from 0.561 to 0.749). The decrease in the number of YLG appears to be due to (a) an overall reduction in the (absolute) size of the outcome elasticities; and (b) a shift in the additional expenditure towards those programmes with a relatively high cost of a life-year. For example, the cost of a life-year for the 'small six' programmes is much larger than for the 'big four PBCs'. However, in 2007/8 the spend elasticity for the small six increases from 0.561 to 0.961 (71%), whereas the expenditure elasticity for the big four rises from 0.528 to 0.559 (6%). A similar pattern – of additional expenditure shifting away from the low cost PBCs – can be seen within the big four programmes. However, it is not clear why such rather dramatic changes should have taken place.

Table 90 presents cost of life-year estimates (adjusted for the mismatch in the ICD-10 coverage of the expenditure and mortality data) for various combinations of programmes. These reveal similar increases in the cost of a life-year between 2006/7 on the one hand and 2007/8 and 2008/9 on the other. The cost of a life-year increased from £19,965 in 2006/7 to £28,983 in 2007/8 for the 10 programmes with mortality rate, an increase of 45%; it increased from £22,565 to £31,846 for all programmes if we assume a zero health gain in PBC 23 and the same gain in the other 12 programmes as in the 10 with a mortality rate (an increase of 41%).

One reason for this apparent step change in the cost of a life-year might be the adjustment that was made to the methodology for the collection of the 2007/8 PB data. In previous years, expenditure that was not directly attributable to a particular programme category was apportioned using admitted patient care percentages.[aj] In other words, if *x*% of total admitted patient care expenditure was allocated to PBC 1, then *x*% of all expenditure that was not directly attributable to a particular programme category was also allocated to PBC 1. With effect from 2007/8, however, NHS organisations were asked to select an appropriate basis for the apportionment of this non-programme-specific expenditure and that, where no reasonable basis existed, such expenditure was to be allocated to the 'other – miscellaneous' (PBC 23X) category.

The Department of Health estimates that this allocation rule change increased the amount of expenditure attributed to PBC 23X by £700M. It will also, of course, have reduced expenditure across other programmes by the same amount in total. However, not all programmes will have been equally affected; PBCs that are more heavily inpatient based would have 'lost' expenditure whereas others, such as learning disabilities, social care and mental health, will have 'lost' considerably less. In addition, not all PCTs will have been equally affected because each will have employed different apportionment rules for the non-programme-specific expenditure (Bryn Shorney, personal communication).

Although this allocation rule change has considerably increased the estimated cost of a life-year, we believe that this rule change has led to a more accurate allocation of expenditure across PBCs, and that the more recent estimates of the cost of a life-year (for 2007/8 and 2008/9) are more accurate than those for the earlier years (for 2005/6 and 2006/7).

Adjusting the cost of a life-year estimates to constant prices

The cost of a life-year estimates presented above are all at current prices. To put them on a constant price basis, we need an index of pay and price inflation for the labour and goods/services purchased by the NHS. Curtis[87] reports a pay and prices index for HCHSs and this implies an inflation rate of 3.7% in 2006/7, 2.9% in 2007/8 and 3.9% in 2008/9.[ak] If we assume that similar inflation rates also apply to the purchase of pharmaceuticals and the provision of primary care (items that are excluded from the HCHS index), then we can use these figures to put the cost of a life-year estimates on a constant price basis.

TABLE 87 Table showing cost of life and life-year estimates using spend data for 2008/9 and outcome data for 2008/9/10 (assumes zero health gain for 13 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2008/9	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2008/9/10	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
1	Cancer	4843	0.525	25.43	61,899	0.307	99.77	254,855
2	Circulatory problems	6655	0.648	43.12	38,075	1.319	325.43	132,514
3	Respiratory problems	3994	0.652	26.04	10,660	1.808	125.66	207,230
4	Gastrointestinal problems	3989	0.456	18.19	6015	1.364	37.41	486,199
Big four programmes summary								
5	Spend 2008 and mortality 2008/9/10	19,481		112.78	116,649		588.27	191,716
6	Spend 2007 and mortality 2007/8/9	18,134		101.29	118,059		525.37	192,795
7	Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801		665.10	137,188
8	Spend 2006 and mortality 2004/5/6	17,268		114.04	125,290		953.13	119,650
9	Spend 2005 and mortality 2002/3/4	17,625		141.22	125,290		909.96	155,196
10	Infectious diseases	1201	1.545	18.56	1828	0.504	14.23	1,303,576
11	Endocrine problems	2222	0.484	10.75	1398	1.170	7.92	1,358,473
12	Neurological problems	3466	0.980	33.97	711	0.417	2.91	11,690,226
13	Genitourinary problems	3779	0.697	26.34	240	1.615	2.70	9,749,742
14	Trauma and injuries	3255	1.344	43.75	983	0.000	0.00	N/A
15	Maternity and neonates	3978	0.975	38.79	2156	0.125	2.63	14,760,668
Other six programmes summary								
16	Spend 2008 and mortality 2008/9/10	17,901		172.15	7316		30.39	5,665,475
17	Spend 2007 and mortality 2007/8/9	16,300		156.65	7648		32.85	4,768,699
18	Spend 2006 and mortality 2006/7/8	15,643		93.29	7839		16.14	5,780,723
19	Spend 2006 and mortality 2004/5/6	15,643		112.13	7923		18.17	6,172,491

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2008/9/10	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
0.984	101.39	250,777	2,170,660	1166	0.984	1185	21,802	21,454
0.992	328.06	131,454	1,285,026	3661	0.992	3691	11,779	11,685
0.773	162.56	160,189	311,034	1222	0.773	1581	21,307	16,470
0.571	65.52	277,620	341,884	709	0.571	1241	25,662	14,653
	657.53	171,552	4,108,604	6758		7698	16,688	14,650
	604.62	167,526	4,161,720	6197		7324	16,345	13,830
	761.49	119,823	4,238,786	7399		8604	12,333	10,604
			4,335,559	10,576			10,783	
			4,516,953	10,986			12,855	
1.000	14.23	1,303,576	100,078	260	1.000	260	71,432	71,432
0.634	12.49	861,272	54,779	103	0.634	163	104,008	65,941
0.136	21.36	1,589,871	64,222	87	0.136	643	388,267	52,804
0.172	15.71	1,676,956	8004	30	0.172	175	877,038	150,851
0.175	0.00	N/A	6881	0	0.175	0	N/A	N/A
8.213	0.32	121,229,365	479,905	195	0.679	287	198,939	135,080
	64.11	2,685,119	713,869	676		1528	254,794	112,674
	102.95	1,521,610	745,429	571		1575	274,309	99,428
	25.05	3,724,129	762,991	362		639	258,046	146,108
			757,531	249			449,706	

TABLE 87 Table showing cost of life and life-year estimates using spend data for 2008/9 and outcome data for 2008/9/10 (assumes zero health gain for 13 programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2008/9	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2008/9/10	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
20	Spend 2005 and mortality 2002/3/4	12,743		99.44	7923		16.26	6,115,621
All 10 programmes summary								
21	Spend 2008 and mortality 2008/9/10	37,382		284.93	123,965		618.66	460,562
22	Spend 2007 and mortality 2007/8/9	34,434		257.94	125,707		558.22	462,067
23	Spend 2006 and mortality 2006/7/8	32,911		184.53	128,640		681.24	270,881
24	Spend 2006 and mortality 2004/5/6	32,911		226.18	133,213		971.30	232,861
25	Spend 2005 and mortality 2002/3/4	30,368		240.67	133,213		926.22	259,838
Assume zero health gain in the other 13 programmes: other 13 programmes summary								
26	Spend 2008 and mortality 2008/9/10	41,016		499.05			0.00	
27	Spend 2007 and mortality 2007/8/9	39,223		478.63			0.00	
28	Spend 2006 and mortality 2006/7/8	34,985		494.43			0.00	
29	Spend 2006 and mortality 2004/5/6	34,985		452.78			0.00	
30	Spend 2005 and mortality 2002/3/4	33,942		402.43			0.00	

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2008/9/10	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
			751,009	337			295,074	
	721.64	394,836	4,822,473	7434		9226	38,328	30,883
	707.57	364,540	4,907,149	6768		8900	38,110	28,983
	786.54	234,617	5,001,777	7760		9243	23,780	19,965
			5,093,090	10,826			20,893	
			5,267,962	11,322			21,256	
	0.00			0		0		
	0.00			0		0		
				0		0		
				0				
				0				

TABLE 87 Table showing cost of life and life-year estimates using spend data for 2008/9 and outcome data for 2008/9/10 (assumes zero health gain for 13 programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2008/9	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2008/9/10	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
All 23 programmes								
31	Spend 2008 and mortality 2008/9/10	78,398		783.98			618.66	1,267,229
32	Spend 2007 and mortality 2007/8/9	73,657		736.57			558.22	1,319,496
33	Spend 2006 and mortality 2006/7/8	67,896		678.96			681.24	996,655
34	Spend 2006 and mortality 2004/5/6	67,896		678.96			971.30	699,024
35	Spend 2005 and mortality 2002/3/4	64,310		643.10			926.22	694,330

N/A, not applicable.

Note

All 23 programmes spend: 2008/9 £78,398; 2007/8 £73,657; 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2008/9 1.00%; 2007/8 1.00%; 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2008/9 0.01; 2007/8 0.01; 2006/7 0.01; 2005/6 0.01.
Change in budget: 2008/9 £783.98; 2007/8 £736.57; 2006/7 £678.96; 2005/6 £643.10.
The annual mortality figures reported in cells F7 and F8, and F17 and F18 are identical because we do not have mortality data for 2002/3/4.
For expenditure in 2008/9, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.
The adjustment for the coverage of the mortality and YLL data relative to the spend data uses deaths under age 75 years in England in 2008.
The YLL figure for trauma and injuries has been estimated assuming that each death is on average at age 67 years so that, on average, 7 years of life are lost per death.
The YLL for maternity and neonates is estimated as [(6339 neonate deaths × 75 years) + (128 maternal deaths × 35 years)]. This totals 479,905 life-years.

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2008/9/10	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
	721.64	1,086,385		7434		9226	105,460	84,974
	707.57	1,040,992		6768		8900	108,829	82,765
	786.54	863,228		7760		9243	87,494	73,457
				10,826			62,718	
				11,322			56,799	

TABLE 88 Table showing cost of life and life-year estimates using spend data for 2008/9 and outcome data for 2008/9/10 (assumes zero health gain for PBC 23 and average gain for other 12 programmes)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2008/9	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2008/9/10	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
1	Cancer	4843	0.525	25.43	61,899	0.307	99.77	254,855
2	Circulatory problems	6655	0.648	43.12	38,075	1.319	325.43	132,514
3	Respiratory problems	3994	0.652	26.04	10,660	1.808	125.66	207,230
4	Gastrointestinal problems	3989	0.456	18.19	6015	1.364	37.41	486,199
Big four programmes summary								
5	Spend 2008 and mortality 2008/9/10	19,481		112.78	116,649		588.27	191,716
6	Spend 2007 and mortality 2007/8/9	18,134		101.29	118,059		525.37	192,795
7	Spend 2006 and mortality 2006/7/8	17,268		91.24	120,801		665.10	137,188
8	Spend 2006 and mortality 2004/5/6	17,268		114.04	125,290		953.13	119,650
9	Spend 2005 and mortality 2002/3/4	17,625		141.22	125,290		909.96	155,196
10	Infectious diseases	1201	1.545	18.56	1828	0.504	14.23	1,303,576
11	Endocrine problems	2222	0.484	10.75	1398	1.17	7.92	1,358,473
12	Neurological problems	3466	0.980	33.97	711	0.417	2.91	11,690,226
13	Genitourinary problems	3779	0.697	26.34	240	1.615	2.70	9,749,742
14	Trauma and injuries	3255	1.344	43.75	983	0.000	0.00	N/A
15	Maternity and neonates	3978	0.975	38.79	2156	0.125	2.63	14,760,668
Other six programmes summary								
16	Spend 2008 and mortality 2008/9/10	17,901		172.15	7316		30.39	5,665,475
17	Spend 2007 and mortality 2007/8/9	16,300		156.65	7648		32.85	4,768,699
18	Spend 2006 and mortality 2006/7/8	15,643		93.29	7839		16.14	5,780,723
19	Spend 2006 and mortality 2004/5/6	15,643		112.13	7923		18.17	6,172,491

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2008/9/10	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
0.984	101.39	250,777	2,170,660	1166	0.984	1185	21,802	21,454
0.992	328.06	131,454	1,285,026	3661	0.992	3691	11,779	11,685
0.773	162.56	160,189	311,034	1222	0.773	1581	21,307	16,470
0.571	65.52	277,620	341,884	709	0.571	1241	25,662	14,653
	657.53	171,552	4,108,604	6758		7698	16,688	14,650
	604.62	167,526	4,161,720	6197		7324	16,345	13,830
	761.49	119,823	4,238,786	7399		8604	12,333	10,604
			4,335,559	10,576			10,783	
			4,516,953	10,986			12,855	
1.000	14.23	1,303,576	100,078	260	1.000	260	71,432	71,432
0.634	12.49	861,272	54,779	103	0.634	163	104,008	65,941
0.136	21.36	1,589,871	64,222	87	0.136	643	388,267	52,804
0.172	15.71	1,676,956	8004	30	0.172	175	877,038	150,851
0.175	0.00	N/A	6881	0	0.175	0	N/A	N/A
8.213	0.32	121,229,365	479,905	195	0.679	287	198,939	135,080
	64.11	2,685,119	713,869	676		1528	254,794	112,674
	102.95	1,521,610	745,429	571		1575	274,309	99,428
	25.05	3,724,129	762,991	362		639	258,046	146,108
			757,531	249			449,706	

TABLE 88 Table showing cost of life and life-year estimates using spend data for 2008/9 and outcome data for 2008/9/10 (assumes zero health gain for PBC 23 and average gain for other 12 programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2008/9	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2008/9/10	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
20	Spend 2005 and mortality 2002/3/4	12,743		99.44	7923		16.26	6,115,621
All 10 programmes summary								
21	Spend 2008 and mortality 2008/9/10	37,382		284.93	123,965		618.66	460,562
22	Spend 2007 and mortality 2007/8/9	34,434		257.94	125,707		558.22	462,067
23	Spend 2006 and mortality 2006/7/8	32,911		184.53	128,640		681.24	270,881
24	Spend 2006 and mortality 2004/5/6	32,911		226.18	133,213		971.30	232,861
25	Spend 2005 and mortality 2002/3/4	30,368		240.67	133,213		926.22	259,838
Other 13 PBCs? Assume zero health gain in PBC 23 …								
26	PBC 23 spend 2008 and mortality 2008/9/10	11,663	0.494	57.62			0.00	
27	PBC 23 spend 2007 and mortality 2007/8/9	11,763	0.563	66.23			0.00	
28	PBC 23 spend 2006 and mortality 2006/7/8	10,585	0.739	78.22			0.00	
29	PBC 23 spend 2006 and mortality 2004/5/6	10,585	0.759	80.34			0.00	
30	PBC 23 spend 2005 and mortality 2002/3/4	8449	0.926	78.24			0.00	
… and that the gain in 10 PBCs (see row 21) applies to the remaining 12 PBCs								
31	12 PBCs spend 2008 and mortality 2008/9/10	29,353		441.43			958.47	460,562
32	12 PBCs spend 2007 and mortality 2007/8/9	27,460		412.41			892.53	462,067
33	12 PBCs spend 2006 and mortality 2006/7/8	24,400		416.20			1536.48	270,881

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2008/9/10	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
			751,009	337			295,074	
	721.64	394,836	4,822,473	7434		9226	38,328	30,883
	707.57	364,540	4,907,149	6768		8900	38,110	28,983
	786.54	234,617	5,001,777	7760		9243	23,780	19,965
			5,093,090	10,826			20,893	
			5,267,962	11,322			21,256	
	0.00			0.00		0.00		
	0.00			0.00		0.00		
				0.00		0.00		
				0.00				
				0.00				
	1118.02	394,836		11,517		14,294	38,328	30,883
	1131.31	364,540		10,821		14,229	38,110	28,983
	1773.97	234,617		17,502		20,847	23,780	19,965

TABLE 88 Table showing cost of life and life-year estimates using spend data for 2008/9 and outcome data for 2008/9/10 (assumes zero health gain for PBC 23 and average gain for other 12 programmes) (*continued*)

(A) PBC scenario	(B) PBC description	(C) Spend (£M) 2008/9	(D) Spend elasticity	(E) (= 0.01 × C × D) change in spend (£M)	(F) Annual mortality, < 75 years, 2008/9/10	(G) Outcome elasticity (without negative sign)	(H) (= 0.01 × D × F × G) change in annual mortality	(I) (= E/H) cost per life gained (£)
34	12 PBCs spend 2006 and mortality 2004/5/6	24,400		372.44			1599.42	232,861
35	12 PBCs spend 2005 and mortality 2002/3/4	25,493		324.20			1247.69	259,838
All 23 programmes								
36	23 PBCs spend 2008 and mortality 2008/9/10	78,398		783.98			1577.13	497,094
37	23 PBCs spend 2007 and mortality 2007/8/9	73,657		736.57			1450.75	507,717
38	23 PBCs spend 2006 and mortality 2006/7/8	67,896		678.96			2217.72	306,153
39	23 PBCs spend 2006 and mortality 2004/5/6	67,896		678.96			2570.72	264,113
40	23 PBCs spend 2005 and mortality 2002/3/4	64,310		643.10			2173.90	295,827

N/A, not applicable.

Note

All 23 programmes spend: 2008/9 £78,398; 2007/8 £73,657; 2006/7 £67,896; 2005/6 £64,310.
% change in budget: 2008/9 1.00%; 2007/8 1.00%; 2006/7 1.00%; 2005/6 1.00%.
Proportionate change: 2008/9 0.01; 2007/8 0.01; 2006/7 0.01; 2005/6 0.01.
Change in budget: 2008/9 £783.98; 2007/8 £736.57; 2006/7 £678.96; 2005/6 £643.10.
The annual mortality figures reported in cells F7 and F8, and F17 and F18 are identical because we do not have mortality data for 2002/3/4.
For expenditure in 2008/9, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.
For expenditure in 2007/8, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.
The adjustment for the coverage of the mortality and YLL data relative to the spend data uses deaths under age 75 years in England in 2008.

(J) Coverage of mortality data relative to spend data	(K) (= H/J) change in annual mortality adjusted for coverage	(L) (= E/K) cost per life gained (£) adjusted for coverage	(M) Total life-years lost, < 75 years, 2008/9/10	(N) (= 0.01 × D × G × M/3) change in annual life-years lost	(O) Coverage of mortality data relative to spend data	(P) (= N/O) change in annual life-years lost adjusted for coverage	(Q) (= E/N) cost per YLG (£)	(R) (= E/P) cost per YLG adjusted for coverage (£)
				17,826			20,893	
				15,252			21,256	
	1839.66	426,155		18,951		23,520	41,369	33,333
	1838.88	400,554		17,590		23,129	41,875	31,846
	2560.50	265,167		25,262		30,090	26,876	22,565
				28,652			23,697	
				26,575			24,200	

TABLE 89 Table showing expenditure and outcome elasticities for five combinations of expenditure and outcome data, and corresponding (unadjusted) cost of life-year estimates

		Spend elasticities					Outcome elasticities	
(A)	(B) PBC description	(C) Using spend for 2005 and mortality for 2002/3/4	(D) Using spend for 2006 and mortality for 2004/5/6	(E) Using spend for 2006 and mortality for 2006/7/8	(F) Using spend for 2007 and mortality for 2007/8/9	(G) Using spend for 2008 and mortality for 2008/9/10	(H) Using spend for 2005 and mortality for 2002/3/4	(I) Using spend for 2006 and mortality for 2004/5/6
1	Cancer	0.968	0.548	0.465	0.890	0.525	–0.394	–0.337
2	Circulatory problems	0.682	0.701	0.540	0.293	0.648	–1.370	–1.447
3	Respiratory problems	0.849	0.718	0.679	0.536	0.652	–1.574	–3.507
4	Gastrointestinal problems	0.772	0.667	0.446	0.622	0.456	–2.018	–2.137
5	All big four PBCs	0.801	0.660	0.528	0.559	0.579	–0.941	–1.083
6	Infectious diseases	0.742	0.731	0.792	1.436	1.545	–0.152	–0.030
7	Endocrine problems	0.425	0.966	0.953	0.264	0.484	–0.244	–0.812
8	Neurological problems	1.111	0.648	0.616	1.035	0.980	–0.182	–0.098
9	Genitourinary problems	1.041	0.837	0.912	1.004	0.697	–0.034	–0.073
10	Trauma and injuries	0.627	0.617	0.358	1.686	1.344	–1.332	–0.527
11	Maternity and neonates	0.388	0.601	0.224	0.514	0.975	–0.237	–0.035
12	All small six PBCs	0.780	0.717	0.596	0.961	0.962	–0.262	–0.122
13	All 10 PBCs with mortality indicator	0.792	0.687	0.561	0.749	0.762	–0.844	–0.940
14	All 23 PBCs assuming zero gain in PBCs without mortality indicator	N/A	N/A	N/A	N/A	N/A	N/A	N/A
15	GMS/PMS	0.926	0.759	0.739	0.563	0.494	N/A	N/A
16	All 23 PBCs assuming zero gain in PBC 23 but average gain in other PBCs without a mortality indicator	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A, not applicable.

Notes

The spend and outcome elasticities reported for groups of programmes are the implied elasticites calculated from the totals for the relevant individual programmes [i.e. group spend elasticity = (PBC spend × PBC spend elasticity)/PBC spend, and group outcome elasticity = (PBC mortality × PBC outcome elasticity)/PBC mortality]. For the purpose of the calculation of the implied group outcome elasticity, we have used the YLL as the mortality indicator. The implied group elasticities are directly comparable with the individual programme elasticities as both exclude the impact of the relevant budget elasticities. The implied group elasticities cannot be used to calculate directly the cost of a life (year) for a group of PBCs. Instead, the latter should be calculated by summing across the change in spend and the change in mortality for the individual PBCs within the group.

For each individual programme: the cost of an additional life-year = expenditure elasticity × annual spend/(expenditure elasticity × outcome elasticity × annual life-years lost).

For a group of programmes: the overall cost of an additional life-year = ∑(annual spend × spend elasticity)/(spend elasticity × outcome elasticity × annual life-years lost).

The results using expenditure for 2006/7 and mortality for 2004/5/6 incorporate MFFs for HCHS and prescribing (see *Tables 63* and *64*).

			Cost of an additional life-year (£) (unadjusted for YLL coverage)				
(J) Using spend for 2006 and mortality for 2006/7/8	(K) Using spend for 2007 and mortality for 2007/8/9	(L) Using spend for 2008 and mortality for 2008/9/10	(M) Using spend for 2005 and mortality for 2002/3/4	(N) Using spend for 2006 and mortality for 2004/5/6	(O) Using spend for 2006 and mortality for 2006/7/8	(P) Using spend for 2007 and mortality for 2007/8/9	(Q) Using spend for 2008 and mortality for 2008/9/10
–0.342	–0.365	–0.307	13,741	16,518	16,383	17,165	21,802
–1.434	–1.277	–1.319	8328	8725	9466	11,315	11,779
–2.622	–2.205	–1.808	20,601	8747	11,593	14,798	21,307
–1.536	–1.328	–1.364	18,303	15,795	20,892	25,034	25,662
–0.965	–0.872	–0.825	12,855	10,783	12,333	16,345	16,688
–0.047	–0.548	–0.504	215,054	1,036,377	630,798	57,742	71,432
–0.842	–0.566	–1.170	371,601	112,882	114,416	190,745	104,008
–0.112	–0.339	–0.417	503,201	1,241,253	1,129,960	431,749	388,267
–0.051	–1.855	–1.615	29,144,918	12,384,965	20,421,090	652,096	877,038
0.000	–0.369	0.000	282,132	548,767	N/A	1,115,197	N/A
–0.482	–0.110	–0.125	17,490	631,700	45,158	204,168	198,939
–0.392	–0.254	–0.300	295,074	449,706	258,046	274,309	254,794
–0.877	–0.778	–0.747	21,256	20,893	23,780	38,110	38,328
N/A	N/A	N/A	56,799	62,718	87,494	108,829	105,460
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	24,200	23,697	26,876	41,875	41,369

TABLE 90 Table showing adjusted cost of life-year estimates for various combinations of programmes

		Cost per life-year (£) (adjusted for ICD-10 coverage of spend and mortality data)		
(A)	(B) PBC description	(C) 2006/7	(D) 2007/8	(E) 2008/9
1	Cancer	16,121	16,891	21,454
2	Circulatory disease	9390	11,224	11,685
3	Respiratory problems	8961	11,439	16,470
4	Gastrointestinal problems	11,929	14,295	14,653
5	All big four programmes	10,604	13,830	14,650
6	Other six programmes with a mortality rate	146,108	99,428	112,674
7	All 10 PBCs with a mortality rate	19,965	28,983	30,883
(a) if we assume a zero health gain in those PBCs without a mortality rate . . .				
8	All 23 programmes	73,457	82,765	84,974
. . . or (b) if we assume a zero gain in PBC 23 and that the average gain from the 10 PBCs with a mortality rate is applied to the remaining programmes				
9	All 23 programmes	22,565	31,846	33,333

Note that the figures for 2006/7 relate to the use of mortality for 2006/7/8 combined.

For example, if we assume that PBC 23 generates a zero health gain and that the gain attributable to the 12 programmes without a mortality indicator is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes in 2008/9 is £33,333 at current (2008/9) prices. The cost for 2007/8 is £31,846 at current (2007/8) prices or £33,088 at constant (2008/9) prices, and the figure for 2006/7 is £22,565 at current (2006/7) prices or £24,125 at constant (2008/9) prices. The conversion of the costs from a current to constant price basis has relatively little impact because the inflation rate over the relevant period is quite small.

Summary and conclusions

In this section we have estimated outcome and expenditure models using PB data for 2008/9 and mortality data for 2008/9/10. The cost of an additional life-year for all 10 programmes with a mortality-based outcome is £30,883. This is similar to the comparable figure (£28,983) for the previous year (i.e. using expenditure data for 2007/8 and mortality data for 2007/8/9). If we assume that PBC 23 generates a zero health gain and that the gain attributable to the 12 programmes without a mortality indicator is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes in 2008/9 is £33,333 and this, too, is similar to the figure for the previous year (£31,846).

We have also identified a pay and prices index that can be used to put the estimated costs on a constant price basis. This index has recorded an annual inflation rate of about 3.5% since 2005/6.

There appears to have been a step change in the cost of an additional life-year. The cost of a life-year estimates are very similar up to and including 2006/7, and they are very similar for 2007/8 and 2008/9. However, there is a substantial difference between the figures for 2004/5, 2005/6 and 2006/7 on the one hand, and for 2007/8 and 2008/9 on the other. The reason for this step change is not obvious but it might be due to changes in the algorithm used by the Department of Health to allocate non-admitted patient care activity to budget categories. Although this allocation rule change has considerably increased the estimated cost of a life-year, we believe that this rule change has led to a more accurate allocation of

expenditure across PBCs, and that the more recent estimates of the cost of a life-year (for 2007/8 and 2008/9) are more accurate than those for the earlier years (for 2005/6 and 2006/7).

Summary and concluding remarks

The findings presented in this report build on four previous studies.[59,60,62,63] These studies and the results presented here draw on the availability of two new data sets to obtain empirical estimates of the relationship between mortality and expenditure across all English local health authorities.

In this research we have extended the previous studies in several ways. First, we have derived plausible outcome and expenditure models for a larger number of programmes ($n = 10$) than previous studies. The cost of a life-year across all 10 programmes with a mortality-based outcome indicator using expenditure data for 2006/7 and mortality data for 2004/5/6 is £20,893.

Second, we relate expenditure in time period t to mortality in that period (t) and in the next two periods ($t + 1$ and $t + 2$). In other words, we assume that the health benefits associated with expenditure occur either in the same period as the expenditure or in the next two periods. This is an improvement on past practice where data constraints forced researchers to relate expenditure to the current and two previous periods. When we re-estimated our models having replaced mortality data for 2004/5/6 with that of 2006/7/8, we found that the cost of a life-year across the 10 programmes with a mortality-based outcome indicator using expenditure data for 2006/7 is £23,780 (up from £20,893, an increase of 14%).

Third, we have noted the mismatch in the ICD-10 coverage of the expenditure and mortality data. If we adjust the calculation of the cost of a life-year for 2006/7 for this mismatch then the cost of a life-year across the 10 programmes with a mortality-based outcome indicator declines from £23,780 to £19,965 (a decrease of 16%).

Fourth, previous estimates of the cost of a life-year have been for individual programmes of care. In this report we have presented estimates of the cost of a life-year for an enlarged number of programmes and, with the aid of assumptions about the productivity (health gain) of programmes without a meaningful mortality-based outcome indicator, we have extended our individual programme estimates to incorporate expenditure across all programmes of care. Thus, for 2006/7 the cost of a life-year for those PBCs with a mortality-based outcome indicator is £19,965. If we assume that (a) that the health gains associated with PBC 23, which includes primary care and workforce training expenditure, are reflected in the mortality rates for disease-specific programmes and (b) that the average health gain across the other programmes without a mortality-based outcome indicator is the same as that for those PBCs with a mortality-based outcome indicator, then the cost of life-year across all programmes is £22,565.

Fifth, we have extended our cost of life-year estimates beyond 2006/7. Re-estimation of our model using budgeting expenditure for 2007/8 generates an all programme cost of a life-year estimate of £31,846, and re-estimation of our model using budgeting expenditure for 2008/9 generates a similar cost of a life-year estimate (£33,333). Together, the last two estimates suggest that there has been a step change in the cost of a life-year, and that this appears to have occurred between 2006/7 and 2007/8. The cost of a life-year estimates are very similar up to and including 2006/7, and they are very similar for 2007/8 and 2008/9. However, there is a substantial difference between the figures for 2004/5, 2005/6 and 2006/7 on the one hand (at about £22,000), and for 2007/8 and 2008/9 on the other (at about £33,000). The reason for this step change is not obvious but it might be due to changes in the algorithm used by the Department of Health to allocate non-admitted patient care activity to budget categories. Although this allocation rule change has considerably increased the estimated cost of a life-year, we believe that this rule change has led to a more accurate allocation of expenditure across PBCs, and that the more recent estimates of the cost of a life-year (for 2007/8 and 2008/9) are more accurate than those for the earlier years (for 2005/6 and 2006/7).

Virtually all of the cost of a life-year estimates presented in this report are at current prices. However, it is possible to put them on a constant price basis using the HCHSs pay and prices index.[87] For 2006/7, 2007/8 and 2008/9 this index recorded an annual rate of inflation of about 3.5% and so the impact of this constant price adjustment is fairly minimal. For example, if we assume that PBC 23 generates a zero health gain and that the gain attributable to the 12 programmes without a mortality indicator is, on average, the same as that attributable to those with a mortality outcome measure, then the cost of a life-year across all programmes at constant 2008/9 prices is £33,333 for 2008/9, £33,088 for 2007/8, and £24,125 for 2006/7.

Finally, although previous results and our current models 'pass' the appropriate statistical tests and, in particular, the Hansen–Sargen test for valid instruments, we are aware that this test might be unable to detect the presence of invalid instruments in some (albeit rather restrictive) circumstances. Responding to this, several studies have suggested that researchers using IV techniques should subject the estimated coefficient on the endogenous variable to a sensitivity analysis. We do precisely this for the outcome equation for each of the big four models. This sensitivity analysis reveals that uncertainty associated with instrument validity has little effect on our estimate of the cost of a life-year, but it does increase the degree of uncertainty associated with this estimate.

We recognise that this study has a number of limitations. The cost of an additional life-year estimates for those programmes with a mortality-based outcome indicator are unadjusted for the QoL during the additional year; the quoted costs will be an underestimate of the QALY-adjusted cost of a life-year to the extent that additional life-years are not in perfect health. In previous studies we have noted that a rudimentary adjustment for this issue using HODaR data increased the cost of a life-year by about 50–60%.[12,100]

At the same time, however, the estimated costs will exaggerate the cost of an additional QALY-adjusted year for those programmes with a mortality-based outcome indicator because they ignore any health benefits that are not associated with a reduction in mortality. In other words, expenditure that improves the QoL (e.g. cancer palliative care) but which does not extend the length of life is implicitly given a zero health gain value.

In addition, the expenditure data relates to expenditure on all patients whereas the mortality data is based on a LE of 75 years. Thus, implicitly our calculations attribute a zero health gain to all expenditure on those aged > 75 years. To illustrate the magnitude of the potential health gain ignored by this restriction, note that in a recent study of costs associated with all inpatient and outpatient activity (excluding mental health), those aged > 75 years accounted for 25% of all costs in 2007/8.[147]

Moreover, our cost of a life-year estimates are based on the assumption that any Departmental budgetary change falls entirely on PCTs. Although PCTs account for most of the Department of Health's budget, non-PCTs still accounted for 15% of the budget in 2006/7. As we have no information on how any budgetary change would be split between PCTs and non-PCTs, we have assumed that that any Departmental budgetary change falls entirely on PCTs. If the non-PCT budget is responsive to changes in the Department's budget then our cost of a life-year estimates will be too low. If the non-PCT budget is as responsive as the PCT budget, then our cost of a life-year estimate for 2006/7 will be increased by 17.7% (that is, from £22,565 to £26,553).

The results presented in this study are all from the estimation of the relationship between expenditure and mortality using data for a single time period. With the availability of several years of data for both expenditure and mortality, we wanted to estimate a panel data model because a panel can offer advantages over a one-period model (e.g. it is better able to handle any unobserved heterogeneity across PCTs). However, most of the instruments employed here are based on the 2001 Census[80] and thus estimation of a panel model will not be possible until these instruments become time variant; this should occur later this year with release of the 2011 Census data at PCT level. This is one piece of work that we intend to pursue in the near future.

Annex

TABLE 91 Table showing national (all PCT) expenditure per head (£) and growth in expenditure (%) by PBC group and subgroup, 2003/4–2008/9

PBC description		Spend (£) per head 2003/4	Spend (£) per head 2004/5	Spend (£) per head 2005/6	Spend (£) per head 2006/7	Spend (£) per head 2007/8	Growth (%) 2007/8	Spend (£) per head 2008/9	Growth (%) 2008/9
1	Infectious diseases	17.95	20.22	23.61	20.88	22.08	6	23.46	6
1A	HIV and AIDS				7.39	8.54	16	10.36	21
1X	Infectious diseases (other)				13.49	13.54	0	13.10	–3
2	Cancers and tumours	64.95	75.54	83.24	81.67	90.21	10	94.55	5
2A	Cancer, head and neck				2.83	2.65	–6	2.72	3
2B	Cancer, upper GI				4.05	4.38	8	4.73	8
2C	Cancer, lower GI				6.46	6.71	4	7.47	11
2D	Cancer, lung				3.89	4.28	10	4.48	5
2E	Cancer, skin				1.88	2.05	9	2.05	0
2F	Cancer, breast				7.39	8.35	13	9.34	12
2G	Cancer, gynaecological				2.97	2.93	–1	3.05	4
2H	Cancer, urological				7.76	7.84	1	8.17	4
2I	Cancer, haematological				8.40	9.22	10	9.47	3
2X	Cancers and tumours (other)				36.04	41.79	16	43.07	3
3	Disorders of the blood	14.08	17.00	17.48	16.58	19.44	17	19.50	0
4	Endocrine, nutritional and metabolic	28.96	31.86	37.26	36.70	39.39	7	43.38	10
4A	Diabetes				17.76	19.44	9	21.73	12

continued

TABLE 91 Table showing national (all PCT) expenditure per head (£) and growth in expenditure (%) by PBC group and subgroup, 2003/4–2008/9 (*continued*)

PBC description		Spend (£) per head 2003/4	Spend (£) per head 2004/5	Spend (£) per head 2005/6	Spend (£) per head 2006/7	Spend (£) per head 2007/8	Growth (%) 2007/8	Spend (£) per head 2008/9	Growth (%) 2008/9
4B	Endocrine, nutritional and metabolic				6.95	7.47	8	7.96	6
4X	Other endocrine, nutritional, metabolic				11.99	12.48	4	13.69	10
5	Mental health disorders	133.31	146.83	158.95	166.53	180.90	9	191.21	6
5A	Substance misuse				13.81	15.76	14	17.81	13
5B	Organic mental disorders				14.24	14.83	4	17.39	17
5C	Psychotic disorders				23.84	31.19	31	33.69	8
5D	Child and adolescent mental health				12.13	12.15	0	13.33	10
5X	Other mental health disorders				102.51	106.97	4	108.99	2
6	Problems of learning disability	37.93	43.37	46.54	48.36	54.20	12	56.11	4
7	Neurological	29.83	35.09	41.06	55.27	62.43	13	67.64	8
7A	Chronic pain				19.31	22.12	15	22.79	3
7X	Neurological (other)				35.96	40.31	12	44.85	11
8	Problems of vision	24.61	27.65	28.24	26.97	30.69	14	32.95	7
9	Problems of hearing	5.73	6.32	6.27	6.21	8.07	30	8.16	1
10	Problems of circulation	110.12	122.37	124.28	122.06	124.77	2	129.94	4
10A	Coronary heart disease				38.91	40.32	4	41.20	2
10B	Cerebrovascular disease				16.05	17.30	8	19.35	12
10C	Problems of rhythm				7.22	8.21	14	8.43	3
10X	Problems of circulation (other)				59.88	58.95	–2	60.96	3
11	Problems of the respiratory system	54.60	62.71	69.56	65.07	67.68	4	77.97	15

TABLE 91 Table showing national (all PCT) expenditure per head (£) and growth in expenditure (%) by PBC group and subgroup, 2003/4–2008/9 (*continued*)

PBC description		Spend (£) per head 2003/4	Spend (£) per head 2004/5	Spend (£) per head 2005/6	Spend (£) per head 2006/7	Spend (£) per head 2007/8	Growth (%) 2007/8	Spend (£) per head 2008/9	Growth (%) 2008/9
11A	Obstructive airways disease				10.64	10.64	0	12.70	19
11B	Asthma				14.04	15.73	12	16.99	8
11X	Problems of the respiratory system, other				40.40	41.31	2	48.27	17
12	Dental problems	10.78	13.55	24.91	51.93	59.45	14	62.44	5
13	Problems of the gastrointestinal system	63.56	73.22	81.30	73.30	75.05	2	77.89	4
13A	Upper GI				19.88	19.51	–2	19.89	2
13B	Lower GI				20.46	21.92	7	22.63	3
13C	Hepatobiliary				11.26	12.23	9	12.90	5
13X	Problems of the gastrointestinal system, other				21.69	21.39	–1	22.46	5
14	Problems of the skin	20.98	24.90	26.84	28.31	30.41	7	32.34	6
14A	Burns				1.08	1.56	44	1.02	–34
14X	Problems of the skin, other				27.23	28.86	6	31.32	9
15	Problems of the musculoskeletal system	61.36	71.72	74.74	66.75	75.91	14	79.68	5
16	Problems due to trauma and injuries	62.31	72.13	76.41	57.29	57.56	0	63.54	10
17	Problems of the genitourinary system	55.32	62.38	67.38	68.98	67.83	–2	73.78	9
17A	Genital tract problems				19.33	18.80	–3	19.36	3
17B	Renal problems				21.54	19.74	–8	22.29	13
17C	STDs				4.26	4.71	10	5.43	15
17X	Problems of the genitourinary system, other				23.85	24.58	3	26.69	9
18	Maternity and Reproductive health	52.28	55.04	60.42	57.64	57.09	–1	60.44	6
19	Conditions of neonates	11.72	13.93	13.42	13.17	15.15	15	17.23	14

continued

TABLE 91 Table showing national (all PCT) expenditure per head (£) and growth in expenditure (%) by PBC group and subgroup, 2003/4–2008/9 (*continued*)

PBC description		Spend (£) per head 2003/4	Spend (£) per head 2004/5	Spend (£) per head 2005/6	Spend (£) per head 2006/7	Spend (£) per head 2007/8	Growth (%) 2007/8	Spend (£) per head 2008/9	Growth (%) 2008/9
20	Adverse effects and poisoning	9.68	12.32	14.25	14.59	15.84	9	18.31	16
20A	Unintended consequences of treatment				10.54	12.14	15	12.96	7
20B	Poisoning				2.13	2.44	15	2.91	19
20C	Violence				0.47	0.49	3	1.75	258
20X	Adverse effects and poisoning, other				1.45	0.77	–47	0.70	–9
21	Healthy individuals	20.29	22.77	26.18	26.85	31.44	17	35.74	14
21A	NSF prevention programme				2.30	3.75	63	4.82	29
21B	NSF mental health prevention				0.17	0.47	176	0.46	–2
21X	Healthy individuals (other)				24.38	27.22	12	30.46	12
22	Social care needs	24.81	30.93	33.59	30.29	35.29	17	36.58	4
23	Other	136.94	157.75	171.82	209.70	232.02	11	227.71	–2
23A	GMS/PMS				141.42	147.53	4	145.26	–2
23B	Training (WDCs)				0.60	0.30	–49	0.24	–21
23X	Miscellaneous				67.67	84.19	24	82.20	–2
1 to 23	All PBCs	1052.12	1199.60	1307.76	1345.10	1452.91	8	1530.59	5

AIDS, acquired immunodeficiency syndrome; GI, gastrointestinal; NSF, National Service Framework; STD, sexually transmitted disease; WDC, Workforce Development Confederation.

Notes

The population figures for 2003/4, 2004/5 and 2005/6 are identical (the total for England is 49,175,998).
The corresponding figure for 2006/7 is 50,476,231, for 2007/8 it is 50,695,989, and for 2008/9 it is 51,220,531.
The spend per head figures are calculated by summing expenditure across all PCTs and dividing by the national population.

TABLE 92 Table showing set of socioeconomic indicators available as potential instruments in the IV estimation

Indicator name	Short description	Long description
BORNEXEU	Residents born outside the EU	Residents born outside the EU divided by all residents (census cell definition: KS005008/KS005001)
WHITEEG	Population in white ethnic group	Population in white ethnic group divided by total population (KS006002 + KS006003 + KS006004)/KS006001
PCWALLTI	Population of working age with illness	Proportion of population of working age with LLT aged 16–74 years (KS008003/KS09A001)
POPPUCAR	Unpaid care providers in population	Proportion of population providing unpaid care (KS008007/KS008001)
POPPUCA1	Unpaid care (< 20 hours/week) in population	Proportion of population providing unpaid care for 1–19 hours a week (KS008008/KS008001)
POPPUCA2	Unpaid care (20–49 hours/ week) in population	Proportion of population providing unpaid care for 20–49 hours per week (KS008009/KS008001)
POPPUCA3	Unpaid care (> 50 hours/week) in population	Proportion of population providing unpaid care for > 50 hours a week (KS008007/KS008001)
NQUAL1674	Proportion aged 16–74 years with no qualifications	Proportion of population aged 16–74 years with no qualifications (KS013002/KS013001
FTSTUDEN	Proportion aged 16–74 years full-time students	Proportion of population aged 16–74 years that are full-time students (KS013008 + KS013009)/KS013001
HHNOCAR	Households without a car	Proportion of households without a car (KS017002/KS017001)
OWNOCC	Owner occupied households	Proportion of households that are owner occupied (KS018002 + KS018003 + KS018004)/KS018001)
LAHARENT	Rented social housing	Proportion of households that are rented from LA or HA (KS018005 + KS018006)/KS018001
PRIVRENT	Rented private housing	Proportion of households that are rented from private landlords (KS018007/KS018001)
LONEPENH	Lone pensioner households	Proportion of households that are one pensioner households (KS020002/KS020001)
LONEPARH	Lone parent households	Proportion of households that are lone parent households with dependent children (KS020011/KS020001)
PERMSICK	Permanently sick of those aged 16–74 years	Proportion of population aged 16–74 years that are permanently sick (KS09A010/KS09A001)
PC74LTUN	Long-term unemployed of those aged 16–74 years	Proportion of those aged 16–74 years that are long-term unemployed (KS09A015/KS09A001)
WORKAGRI	Employed in agriculture	Proportion of those aged 16–74 years in employment that are working agriculture (KS11A002/KS11A001)
PROFOCCU	People in professional occupations	Proportion of those aged 16–74 years in managerial and professional occupations (KS14A002 + KS14A003 + KS14A004)/KS14A001

TABLE 93 Table showing first-stage regressions for outcome models associated with 2005/6 expenditure and mortality data for 2002/3/4

	2005/6, outcome model, instrument spend, unweighted, first stage					
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 16 trauma and injuries	(6) PBC 19 neonates
Need per head	0.406***	1.173***	1.533***	0.970***	0.727**	
	[0.097]	[0.235]	[0.401]	[0.243]	[0.289]	
Lone pensioner households	0.593***	0.229***	−0.118	0.045	0.561***	
	[0.109]	[0.084]	[0.112]	[0.093]	[0.108]	
Provision of unpaid care	−0.013	0.374***		0.574***	−0.148	
	[0.135]	[0.115]		[0.089]	[0.132]	
IMD2000		−0.152***	−0.247***	−0.047	−0.016	
		[0.056]	[0.069]	[0.060]	[0.074]	
White ethnic group		−0.007				
		[0.067]				
Permanently sick			0.192**			
			[0.085]			
Low birth weight births						0.393
						[0.308]
Lone parent households						0.034
						[0.209]
No qualifications						−0.599***
						[0.148]

	2005/6, outcome model, instrument spend, unweighted, first stage					
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 16 trauma and injuries	(6) PBC 19 neonates
Long-term unemployed						0.394***
						[0.122]
LA/HA rented accommodation						0.283**
						[0.127]
Constant	−1.373***	−0.311	−1.562***	−0.959***	−1.780***	−2.797***
	[0.304]	[0.244]	[0.344]	[0.192]	[0.260]	[0.433]
Observations	295	295	295	295	295	294
R^2	0.297	0.629	0.434	0.571	0.396	0.197

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
These are the first-stage regressions for the IV models reported in *Table 42*.

TABLE 94 Table showing first-stage regressions for expenditure models associated with 2005/6 expenditure and mortality data for 2002/3/4

	2005/6, spend model, instrument other programme need, unweighted, first stage						
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 7 neurological	(6) PBC 16 trauma and injuries	(7) PBC 23 GMS/PMS
No qualifications							0.240***
							[0.038]
Lone pensioner households	−0.686***	−0.244***	−0.234***	−0.266***	−0.234***	−0.234***	−0.129***
	[0.067]	[0.052]	[0.049]	[0.049]	[0.049]	[0.049]	[0.038]
Private rented housing							0.072***
							[0.017]
Work in agriculture							−0.006
							[0.008]
PCT budget per head	−0.146	−0.003	−0.077	−0.022	−0.077	−0.077	0.043
	[0.117]	[0.074]	[0.070]	[0.070]	[0.070]	[0.070]	[0.069]
No car households							0.092**
							[0.039]
Lone parent households							0.171***
							[0.035]
Permanently sick							0.125***
							[0.027]
Need per head	1.933***	0.651***	0.875***	0.597***	0.875***	0.875***	
	[0.110]	[0.157]	[0.175]	[0.157]	[0.175]	[0.175]	

	2005/6, spend model, instrument other programme need, unweighted, first stage						
Variable	(1) PBC 2 cancer	(2) PBC 10 circulation	(3) PBC 11 respiratory	(4) PBC 13 gastrointestinal	(5) PBC 7 neurological	(6) PBC 16 trauma and injuries	(7) PBC 23 GMS/PMS
White ethnic group		0.197***					
		[0.038]					
Provision of unpaid care	−0.371***	−0.153**	−0.217***		−0.217***	−0.217***	
	[0.071]	[0.065]	[0.055]		[0.055]	[0.055]	
IMD2000		0.056*	0.128***	0.179***	0.128***	0.128***	
		[0.033]	[0.038]	[0.035]	[0.038]	[0.038]	
Constant	2.562***	4.103***	4.851***	5.114***	4.851***	4.851***	7.361***
	[0.159]	[0.140]	[0.109]	[0.082]	[0.109]	[0.109]	[0.139]
Observations	295	295	295	295	295	295	295
R^2	0.804	0.680	0.858	0.849	0.858	0.858	0.881

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
These are the first-stage regressions for the IV models reported in *Table 43*.

TABLE 95 Table showing first-stage regressions for outcome and expenditure models associated with 2006/7 expenditure and mortality data for 2004/5/6

Variable	(1) PBC 2 cancer, 2006/7, outcome model, uses SYLLR, instrument spend, weighted, first stage, CARAN need, two MFFs	(2) PBC 2, cancer, 2006/7, spend model, uses SYLLR, instrument other programme need, weighted, first stage, CARAN need, two MFFs	(3) PBC 10 circulation, 2006/7, outcome model, uses SYLLR, instrument spend, weighted, first stage, CARAN need, two MFFs	(4) PBC 10 circulation, 2006/7, spend model, uses SYLLR, instrument other programme need, weighted, first stage, CARAN need, two MFFs	(5) PBC 11 respiratory, 2006/7, outcome model, uses SYLLR, instrument spend, weighted, first stage, CARAN need, two MFFs	(6) PBC 11 respiratory, 2006/7, spend model, uses SYLLR, instrument other programme need, weighted, first stage, CARAN need, two MFFs	(7) PBC 13 gastrointestinal, 2006/7, outcome model, uses SYLLR, instrument spend, weighted, first stage, CARAN need, two MFFs	(8) PBC 13 gastrointestinal, 2006/7, spend model, uses SYLLR, instrument other programme need, weighted, first stage, CARAN need, two MFFs
Need CARAN per head	1.162***	1.602***	1.539***	0.606***	1.026***	0.836***	1.292***	0.938***
	[0.250]	[0.126]	[0.323]	[0.141]	[0.368]	[0.175]	[0.358]	[0.167]
Need CARAN per head squared	0.912							
	[0.666]							
Lone pensioner households	0.383***	−0.431***	0.321***	−0.221***				
	[0.134]	[0.073]	[0.111]	[0.067]				
IMD2007	−0.153**		−0.247***	0.117***		0.104**	−0.115	0.107***
	[0.074]		[0.087]	[0.037]		[0.043]	[0.094]	[0.041]
PCT budget per head		0.120		0.183*		0.077		−0.020
		[0.124]		[0.094]		[0.084]		[0.093]
Provision of unpaid care		−0.410***	0.097			−0.309***	0.373*	−0.325***
		[0.088]	[0.197]			[0.090]	[0.215]	[0.078]
White ethnic group			−0.060					
			[0.082]					

Variable	(1) PBC 2 cancer, 2006/7, outcome model, uses SYLLR, instrument spend, weighted, first stage, CARAN need, two MFFs	(2) PBC 2, cancer, 2006/7, spend model, uses SYLLR, instrument other programme need, weighted, first stage, CARAN need, two MFFs	(3) PBC 10 circulation, 2006/7, outcome model, uses SYLLR, instrument spend, weighted, first stage, CARAN need, two MFFs	(4) PBC 10 circulation, 2006/7, spend model, uses SYLLR, instrument other programme need, weighted, first stage, CARAN need, two MFFs	(5) PBC 11 respiratory, 2006/7, outcome model, uses SYLLR, instrument spend, weighted, first stage, CARAN need, two MFFs	(6) PBC 11 respiratory, 2006/7, spend model, uses SYLLR, instrument other programme need, weighted, first stage, CARAN need, two MFFs	(7) PBC 13 gastrointestinal, 2006/7, outcome model, uses SYLLR, instrument spend, weighted, first stage, CARAN need, two MFFs	(8) PBC 13 gastrointestinal, 2006/7, spend model, uses SYLLR, instrument other programme need, weighted, first stage, CARAN need, two MFFs
Permanently sick					0.681**			
					[0.269]			
Long-term unemployed					–0.123***			
					[0.035]			
LLT					–0.785*			
					[0.449]			
Constant	5.586***	3.074***	6.387***	3.790***	3.906***	4.501***	5.496***	5.119***
	[0.235]	[0.887]	[0.363]	[0.703]	[0.474]	[0.595]	[0.314]	[0.657]
Observations	152	152	152	152	152	152	152	152
R^2	0.438	0.846	0.623	0.814	0.623	0.840	0.554	0.827

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
These are the first-stage regressions for the IV models reported in *Table 62*.

TABLE 96 Table showing first-stage regressions for outcome and expenditure models associated with 2006/7 expenditure and mortality data for 2006/7/8

Variable	(1) PBC 2 cancer, 2006/7, outcome model, SYLLR 2006/7/8, instrument spend, weighted, first stage, two MFFs	(2) PBC 2 cancer, 2006/7, spend model, SYLLR 2006/7/8, instrument other programme need, weighted, first stage, two MFFs	(3) PBC 10 circulation, 2006/7, outcome model, SYLLR 2006/7/8, instrument spend, weighted, first stage, two MFFs	(4) PBC 10 circulation, 2006/7, spend model, SYLLR 2006/7/8, instrument other programme need, weighted, first stage, two MFFs	(5) PBC 11 respiratory, 2006/7, outcome model, SYLLR 2006/7/8, instrument spend, weighted, first stage, two MFFs	(6) PBC 11 respiratory, 2006/7, spend model, SYLLR 2006/7/8, instrument other programme need, weighted, first stage, two MFFs	(7) PBC 13 gastrointestinal, 2006/7, outcome model, SYLLR 2006/7/8, instrument spend, weighted, first stage, two MFFs	(8) PBC 13 gastrointestinal, 2006/7, spend model, SYLLR 2006/7/8, instrument other programme need, weighted, first stage, two MFFs
Need CARAN per head	1.162***	1.574***	1.539***	0.791***	1.061***	0.909***	1.292***	1.059***
	[0.250]	[0.138]	[0.323]	[0.157]	[0.386]	[0.167]	[0.358]	[0.166]
Need CARAN per head squared	0.912				0.455			
	[0.666]				[0.599]			
Lone pensioner household	0.383***	−0.375***	0.321***	−0.269***				−0.313***
	[0.134]	[0.079]	[0.111]	[0.067]				[0.072]
IMD2007	−0.153**		−0.247***	0.097**		0.107***	−0.115	0.066
	[0.074]		[0.087]	[0.039]		[0.041]	[0.094]	[0.040]
PCT budget per head		0.126		0.128		0.020		0.040
		[0.136]		[0.101]		[0.090]		[0.091]
Provision of unpaid care		−0.386***	0.097			−0.289***	0.373*	−0.203**
		[0.097]	[0.197]			[0.080]	[0.215]	[0.088]
White ethnic group			−0.060					
			[0.082]					

Variable	(1) PBC 2 cancer, 2006/7, outcome model, SYLLR 2006/7/8, instrument spend, weighted, first stage, two MFFs	(2) PBC 2 cancer, 2006/7, spend model, SYLLR 2006/7/8, instrument other programme need, weighted, first stage, two MFFs	(3) PBC 10 circulation, 2006/7, outcome model, SYLLR 2006/7/8, instrument spend, weighted, first stage, two MFFs	(4) PBC 10 circulation, 2006/7, spend model, SYLLR 2006/7/8, instrument other programme need, weighted, first stage, two MFFs	(5) PBC 11 respiratory, 2006/7, outcome model, SYLLR 2006/7/8, instrument spend, weighted, first stage, two MFFs	(6) PBC 11 respiratory, 2006/7, spend model, SYLLR 2006/7/8, instrument other programme need, weighted, first stage, two MFFs	(7) PBC 13 gastrointestinal, 2006/7, outcome model, SYLLR 2006/7/8, instrument spend, weighted, first stage, two MFFs	(8) PBC 13 gastrointestinal, 2006/7, spend model, SYLLR 2006/7/8, instrument other programme need, weighted, first stage, two MFFs
Permanently sick					0.677**			
					[0.272]			
Long-term unemployed					−0.121***			
					[0.035]			
LLT					−0.798*			
					[0.454]			
Constant	5.586***	3.160***	6.387***	4.132***	3.864***	4.916***	5.496***	4.481***
	[0.235]	[0.963]	[0.363]	[0.729]	[0.493]	[0.637]	[0.314]	[0.654]
Observations	152	152	152	152	152	152	152	152
R^2	0.438	0.821	0.623	0.823	0.624	0.831	0.554	0.857

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
These are the first-stage regressions for the IV models reported in *Table 65*.

TABLE 97 Table showing first-stage regressions for outcome models associated with 2007/8 expenditure

Variable	(1) PBC 2 cancer, 2007/8, instrument spend, weighted, first stage	(2) PBC 2 cancer, 2007/8, instrument spend, weighted, first stage	(3) PBC 10 circulation, 2007/8, instrument spend, weighted, first stage	(4) PBC 11 respiratory, 2007/8, instrument spend, weighted, first stage	(5) PBC 11 respiratory, 2007/8, instrument spend, weighted, first stage
Need CARAN per head	0.582**	0.545***	0.724***	1.251***	1.196***
	[0.284]	[0.105]	[0.168]	[0.094]	[0.113]
No car households					
Lone pensioner households	0.632***	0.644***	0.468***	0.360***	0.269***
	[0.148]	[0.119]	[0.100]	[0.103]	[0.100]
IMD2007	−0.012				
	[0.088]				
Need CARAN per head squared				1.332***	1.338***
				[0.428]	[0.425]
Provision of unpaid care			0.441**		0.200
			[0.174]		[0.160]
Born outside EU					
Diabetes prevalence rate 2007/8					
Permanently sick					
Lone parent households					
Chronic kidney disease prevalence rate 2007/8					
Long-term unemployed					
LLT					
HIV need per head squared					
HIV need per head					
Work in agriculture					

(6) PBC 13 gastrointestinal, 2007/8, instrument spend, weighted, first stage	(7) PBC 13 gastrointestinal, 2007/8, instrument spend, weighted, first stage	(8) PBC 4 endocrine, 2007/8, instrument spend, weighted, first stage	(9) PBC 17 genitourinary, 2007/8, instrument spend, weighted, first stage	(10) PBC 1 infectious disease, 2007/8, instrument spend, weighted, first stage	(11) PBC 18 + 19 maternity and neonates, 2007/8, instrument spend, weighted, first stage	(12) PBC 16 trauma and injuries, 2007/8, instrument spend, weighted, first stage
0.999***	1.047***				1.111***	0.856***
[0.105]	[0.099]				[0.259]	[0.282]
				0.512*		0.288**
				[0.267]		[0.137]
0.199						
[0.133]						
		–0.067		0.325		
		[0.053]		[0.224]		
–0.054***	–0.067***				0.004	–0.079**
[0.018]	[0.017]				[0.041]	[0.039]
		0.358***				
		[0.123]				
		0.307***				
		[0.061]				
			0.029			
			[0.124]			
			0.123**			
			[0.061]			
			0.146**			
			[0.061]			
			0.207			
			[0.134]			
				0.128***		
				[0.031]		
				0.300***		
				[0.044]		
				0.152**		0.126***
				[0.064]		[0.033]

TABLE 97 Table showing first-stage regressions for outcome models associated with 2007/8 expenditure (*continued*)

Variable	(1) PBC 2 cancer, 2007/8, instrument spend, weighted, first stage	(2) PBC 2 cancer, 2007/8, instrument spend, weighted, first stage	(3) PBC 10 circulation, 2007/8, instrument spend, weighted, first stage	(4) PBC 11 respiratory, 2007/8, instrument spend, weighted, first stage	(5) PBC 11 respiratory, 2007/8, instrument spend, weighted, first stage
Work in professional occupation					
No qualifications					
Maternity need per head					
Full-time students					
LA/HA accommodation					
Constant	5.759***	5.747***	6.754***	4.886***	5.172***
	[0.252]	[0.234]	[0.322]	[0.201]	[0.350]
Observations	151	151	151	151	151
R^2	0.369	0.369	0.653	0.659	0.664

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
These are the first-stage regressions for the IV models reported in *Table 81*.

(6) PBC 13 gastrointestinal, 2007/8, instrument spend, weighted, first stage	(7) PBC 13 gastrointestinal, 2007/8, instrument spend, weighted, first stage	(8) PBC 4 endocrine, 2007/8, instrument spend, weighted, first stage	(9) PBC 17 genitourinary, 2007/8, instrument spend, weighted, first stage	(10) PBC 1 infectious disease, 2007/8, instrument spend, weighted, first stage	(11) PBC 18 + 19 maternity and neonates, 2007/8, instrument spend, weighted, first stage	(12) PBC 16 trauma and injuries, 2007/8, instrument spend, weighted, first stage
				0.647***		
				[0.172]		
					−0.214	
					[0.160]	
					0.647***	
					[0.159]	
						0.126
						[0.095]
						−0.197*
						[0.104]
4.531***	4.104***	4.224***	5.269***	4.226***	4.004***	4.766***
[0.281]	[0.057]	[0.390]	[0.209]	[1.007]	[0.297]	[0.339]
151	151	151	147	151	151	151
0.531	0.524	0.436	0.296	0.724	0.407	0.361

TABLE 98 Table showing first-stage regressions for expenditure models associated with 2007/8 expenditure

Variable	(1) PBC 2 cancer, 2007/8, spend model, instrument other programme need, weighted, first stage	(2) PBC 10 circulation, 2007/8, spend model, instrument other programme need, weighted, first stage	(3) PBC 11 respiratory, 2007/8, spend model, instrument other programme need, weighted, first stage
PCT budget per head 2007/8	0.071	0.066	0.039
	[0.137]	[0.123]	[0.105]
Need CARAN per head	1.613***	1.201***	1.050***
	[0.149]	[0.136]	[0.191]
Need CARAN per head squared			0.343
			[0.266]
Lone pensioner households	−0.357***	−0.220***	−0.261***
	[0.067]	[0.060]	[0.063]
Provision of unpaid care	−0.362***	−0.215**	−0.156*
	[0.094]	[0.090]	[0.093]
IMD2007			0.070
			[0.042]
Diabetes prevalence rate 2007/8			
Epilepsy prevalence rate 2007/8			
White ethnic group			
Work in agriculture			
Constant	3.624***	4.454***	4.667***
	[0.969]	[0.848]	[0.735]
Observations	151	151	151
R^2	0.847	0.828	0.861

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
These are the first-stage regressions for the IV models reported in *Table 82*.

(4) PBC 13 gastrointestinal, 2007/8, spend model, instrument other programme need weighted, first stage	(5) PBC 4 endocrine, 2007/8, spend model, instrument other programme need, weighted, first stage	(6) PBC 7 neurological, 2007/8, spend model, instrument other programme need, weighted, first stage	(7) PBC 23 GMS/PMS, etc., 2007/8, spend model, instrument other programme need, weighted, first stage	(8) PBC 16 trauma and injuries, 2007/8, spend model, instrument other programme need, weighted, first stage
–0.034	0.057	0.170	0.360**	0.366***
[0.105]	[0.121]	[0.130]	[0.144]	[0.136]
0.971***	1.090***	1.148***		
[0.188]	[0.198]	[0.137]		
	–0.274***	–0.444***	–0.255***	–0.229***
	[0.063]	[0.055]	[0.061]	[0.072]
–0.296***	–0.181*			0.195**
[0.086]	[0.100]			[0.092]
0.099**	0.067		0.309***	0.276***
[0.043]	[0.045]		[0.043]	[0.039]
	0.008			
	[0.069]			
		0.020		
		[0.049]		
			0.221***	
			[0.060]	
				0.009
				[0.011]
5.298***	4.496***	3.974***	2.054**	2.630***
[0.724]	[0.920]	[0.954]	[0.994]	[0.978]
151	151	151	151	151
0.834	0.860	0.839	0.830	0.824

TABLE 99 Table showing first-stage regressions for outcome models associated with 2008/9 expenditure

Variable	(1) PBC 2 cancer, 2008/9, outcome model, instrument spend, weighted, first stage	(2) PBC 10 circulation, 2008/9, outcome model, instrument spend, weighted, first stage	(3) PBC 11 respiratory, 2008/9, outcome model, instrument spend, weighted, first stage	(4) PBC 13 gastrointestinal, 2008/9, outcome model, instrument spend, weighted, first stage
Need CARAN per head	1.122***	1.274***	1.228***	0.989***
	[0.198]	[0.146]	[0.085]	[0.088]
Lone pensioner households	0.490***	0.426***	0.252**	0.272**
	[0.127]	[0.090]	[0.110]	[0.109]
IMD2007	−0.145**			
	[0.060]			
No car households		−0.188***		
		[0.053]		
Need CARAN per head squared			1.071**	
			[0.426]	
Provision of unpaid care			0.339***	
			[0.117]	
Born outside EU				−0.042***
				[0.016]
Diabetes prevalence rate 2007/8				
Permanently sick				
Epilepsy prevalence rate 2007/8				
Owner occupied households				
Lone parent households				
Chronic kidney disease prevalence rate 2007/8				
Long-term unemployed				
HIV need per head				
HIV need per head squared				

(5) PBC 13 gastrointestinal, 2008/9, outcome model, instrument spend, weighted, first stage	(6) PBC 4 endocrine, 2008/9, outcome model, instrument spend, weighted, first stage	(7) PBC 7 neurological, 2008/9, outcome model, instrument spend, weighted, first stage	(8) PBC 17 genitourinary, 2008/9, outcome model, instrument spend, weighted, first stage	(9) PBC 1 infectious disease, 2008/9, outcome model, instrument spend, weighted, first stage	(10) PBC 18 + 19 maternity and neonates, 2008/9, outcome model, instrument spend, weighted, first stage
1.056***		0.373**			0.659***
[0.087]		[0.175]			[0.236]
		0.287***			
		[0.109]			
	−0.082			0.236	
	[0.091]			[0.214]	
				0.502**	
				[0.227]	
	0.539**			1.393***	
	[0.232]			[0.340]	
−0.060***	0.080***				−0.031
[0.015]	[0.026]				[0.032]
	0.167				
	[0.132]				
	0.380***				
	[0.104]				
		0.486***			
		[0.121]			
		−0.235**			
		[0.113]			
			0.175**		0.013
			[0.080]		[0.106]
			0.089***		
			[0.033]		
			0.148***		
			[0.045]		
				0.471***	
				[0.050]	
				0.146***	
				[0.027]	

TABLE 99 Table showing first-stage regressions for outcome models associated with 2008/9 expenditure (*continued*)

Variable	(1) PBC 2 cancer, 2008/9, outcome model, instrument spend, weighted, first stage	(2) PBC 10 circulation, 2008/9, outcome model, instrument spend, weighted, first stage	(3) PBC 11 respiratory, 2008/9, outcome model, instrument spend, weighted, first stage	(4) PBC 13 gastrointestinal, 2008/9, outcome model, instrument spend, weighted, first stage
No qualifications				
Work in agriculture				
Maternity need per head				
Constant	5.937***	5.435***	5.610***	4.752***
	[0.221]	[0.230]	[0.238]	[0.236]
Observations	151	151	151	151
R^2	0.521	0.612	0.746	0.665

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.

Note
These are the first-stage regressions for the IV models reported in *Table 85*.

(5) PBC 13 gastrointestinal, 2008/9, outcome model, instrument spend, weighted, first stage	(6) PBC 4 endocrine, 2008/9, outcome model, instrument spend, weighted, first stage	(7) PBC 7 neurological, 2008/9, outcome model, instrument spend, weighted, first stage	(8) PBC 17 genitourinary, 2008/9, outcome model, instrument spend, weighted, first stage	(9) PBC 1 infectious disease, 2008/9, outcome model, instrument spend, weighted, first stage	(10) PBC 18 + 19 maternity and neonates, 2008/9, outcome model, instrument spend, weighted, first stage
				–0.751***	–0.092
				[0.189]	[0.113]
				0.150***	
				[0.051]	
					0.834***
					[0.162]
4.167***	6.379***	4.808***	5.363***	6.010***	4.171***
[0.048]	[0.768]	[0.193]	[0.121]	[1.513]	[0.375]
151	151	151	148	151	151
0.648	0.559	0.477	0.378	0.791	0.614

TABLE 100 Table showing first-stage regressions for expenditure models associated with 2008/9 expenditure

Variable	(1) PBC 2 cancer, 2008/9, spend model, instrument other programme need, weighted, first stage	(2) PBC 10 circulatory, 2008/9, spend model, instrument other programme need, weighted, first stage	(3) PBC 11 respiratory, 2008/9, spend model, instrument other programme need, weighted, first stage
PCT budget per head 2008/9	0.090	0.049	0.020
	[0.155]	[0.118]	[0.113]
Need CARAN per head	1.589***	1.215***	1.305***
	[0.168]	[0.133]	[0.129]
Need CARAN per head squared			0.221
			[0.270]
Lone pensioner households	–0.371***	–0.209***	–0.286***
	[0.071]	[0.060]	[0.057]
Provision of unpaid care	–0.349***	–0.236**	–0.266***
	[0.105]	[0.092]	[0.088]
IMD2007			
Diabetes prevalence rate 2007/8			
Epilepsy prevalence rate 2007/8			
Maternity need per head			
White ethnic group			
Constant	3.457***	4.528***	4.687***
	[1.131]	[0.849]	[0.814]
Observations	151	151	151
R^2	0.840	0.828	0.854

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.
Robust standard errors in brackets.
These are the first-stage regressions for the IV models reported in *Table 86*.

(4) PBC 13 gastrointestinal, 2008/9, spend model, instrument other programme need, weighted, first stage	(5) PBC 4 endocrine, 2008/9, spend model, instrument other programme need, weighted, first stage	(6) PBC 7 neurological, 2008/9, spend model, instrument other programme need, weighted, first stage	(7) PBC 18 + 19 maternity and neonates, 2008/9, spend model, instrument other programme need, weighted, first stage
–0.115	0.055	0.180	0.452***
[0.106]	[0.122]	[0.132]	[0.128]
1.042***	1.112***	1.119***	
[0.207]	[0.211]	[0.141]	
	–0.256***	–0.453***	–0.106*
	[0.062]	[0.053]	[0.059]
–0.302***	–0.239**		
[0.099]	[0.119]		
0.099**	0.051		0.223***
[0.045]	[0.048]		[0.044]
	0.067		
	[0.064]		
		0.036	
		[0.044]	
			0.266***
			[0.078]
			0.292***
			[0.065]
5.851***	4.340***	3.858***	1.901**
[0.753]	[0.940]	[0.979]	[0.864]
151	151	151	151
0.830	0.857	0.837	0.843

Appendix 3 Translating mortality effects into life-years and quality-adjusted life-years

Introduction

This appendix describes how the results of the econometric work undertaken to estimate the link between NHS spending and mortality, which was detailed in *Appendix 2*, can be translated in to effects on life-years and QALYs. This appendix presents much of the detail of data and analyses that support *Chapter 4* of the main report.

We present three sequential steps of analysis which lead to estimates of the overall cost per QALY threshold for the NHS:

i. In *From mortality to life-years* we reconsider how the estimated effects on mortality from the econometrics work might better translate into life-years by exploring the limitations of mortality data available at PCT level and the published YLL figures presented in the previous chapter. We explore how these estimates might be improved using additional data and analysis.
ii. In *Adjusting life-years for quality-of-life* we consider how these estimates of life-year effects might be adjusted for the QoL in which they are lived, taking account of the gender and the age at which life-years are gained or lost as well as the disutility associated with particular diseases.
iii. In *Including quality-of-life effects during disease* we explore ways to also take account of those effects on health not directly associated with mortality and life-year effects (i.e. the 'pure' QoL effects) to estimate an overall cost per QALY threshold.

This sequence of analysis is set out and explained based on the analysis of 2006/7 expenditure and mortality data from 2006 to 2008. At the end of each section, we present a summary which includes a central 'best' estimate as well as extreme lower and upper bounds for the cost per life-year and cost per QALY threshold. The core assumptions which underpin these three values are common across sections *From mortality to life-years*, *Adjusting life-years for quality-of-life, Including quality-of-life effects during disease* and *Which programme budget categories matter most?*. The central or 'best' estimate is based on two assumptions one conservative and the other more optimistic with respect to the health effects associated with expenditure. The first is that the health effects of changes in 1 year of expenditure are restricted to 1 year. Analyses in *Appendix 2* uses 3 years of mortality data, but these are averaged to an annual value prior to estimating outcome elasticities. Therefore, the estimated outcome elasticities represent the proportionate effect on mortality in 1 year due to a proportionate change in expenditure. This is likely to underestimate effects on mortality as expenditure that reduces mortality risk for an individual in 1 year may well also reduce their risk over subsequent years; possibly over the whole of their remaining disease duration. Expenditure may also prevent disease in future patient populations. Therefore, total health effects will be underestimated and the cost per life-year or QALY threshold will be overestimated. Although undoubtedly conservative, it may be offset to some extent by the more optimistic assumption used to translate mortality effects into life-years. In common with YLL figures published by NHS IC and the WHO GBD study it is assumed that any death averted by expenditure in 1 year will return the individual to the mortality risk of the general population, i.e. the YLG associated with each death averted are based on what would have been their LE taking account of their of age and gender (using life tables for the general population).

The extreme upper and lower bounds for cost per life-year and cost per QALY thresholds are based on making both assumptions either optimistic (providing the lower bound for the threshold) or conservative (an upper bound for the threshold). The lower bound is based on assuming that health effects are not restricted to 1 year but apply to the remaining disease duration for the population at risk during the

expenditure year (although this still does not account for the effects of expenditure on preventing disease). The upper bound is based on the combination of assuming that health effects are restricted to 1 year and that any death averted is only averted for the minimum duration consistent with the mortality data used to estimate the outcome elasticities in *Appendix 2*. It is very important to note that the lower and upper bounds represent extreme values rather than alternative but plausible views that could reasonably be taken.

The three sequential steps of analysis, which provide a cost per life-year threshold, through a cost per life-year adjusted for quality to a cost per QALY threshold, are explained and detailed in *From mortality to life-years*, *Adjusting life-years for quality of life* and *Including quality of life effects during disease*, using the analysis of 2006 expenditure and mortality data from 2006 to 2008. In *Which programme budget categories matter most?*, further analysis using these data highlight which PBCs have the greatest influence on the overall threshold. An exploration of the impact of the uncertainty over the outcome and spend elasticities in estimates of the threshold is also presented in *How uncertain are the estimates?*. The sequence of analyses is then applied to 2008/9 expenditure and 2008/9/10 mortality data; results of the cost per QALY threshold for the most recent years of analysis are presented in *Re-estimating the cost per quality-adjusted life-year threshold using 2008 expenditure data*. In *Re-estimating the cost per quality-adjusted life-year threshold using 2007 expenditure data* we present our best estimate of the threshold cost per QALY based on the analysis of 2007/8 expenditure and mortality data from 2007 to 2009.

Analysis of 2006/7 expenditure and 2006/7/8 mortality data

From mortality to life-years

In this section we summarise our examination of a number of issues associated with available PCT-based mortality data and the associated published estimates of YLL. We then examine how, given the limited information available about the population at risk in each PBC, we might take proper account of the fact that some of the observed deaths would have occurred anyway (had the same population not been at risk in the particular PBC) when estimating YLL, i.e. taking account of unobserved counterfactual deaths. This allows us to estimate the YLL that better reflects the effect of expenditure on the mortality observed in each PBC, and infer the excess deaths associated with each PBC. Finally, we present the cost per death averted and cost per life-year which accounts for the issues raised in this section.

Mortality and years of life lost coverage

The mortality data that is available at PCT level does not offer full coverage of all deaths across all the ICD-10 codes that make up each PBC. *Table 101* illustrates, using a few PBCs as examples, the mapping of three-digit ICD-10 codes to PBCs [see *Table 101*, column (1)] and the incomplete coverage of these

TABLE 101 Illustrating coverage

PBC		(1) ICD-10 codes covered by the spend data	(2) ICD-10 codes covered by the mortality data (NHS IC)	(3) Coverage of mortality data relative to spend data (2008)
1	Infectious diseases	Large parts of A00–B99	A00–B99	1.000
2	Cancer	C00–C97, D00–D49	C00–C97	0.984
4	Endocrine	E000–E899	E10–E14	0.634
10	Circulatory	I00–I99, Q20–Q28	I00–I99	0.992
11	Respiratory	A150–A169, A190–A199, J000–J989, Q300–Q349, R000–R099	J12–J18, J40–J44, J45–J46	0.773

ICD-10 codes in mortality data [see *Table 101*, column (2)]. A more detailed account of the extent of coverage is presented in *Table 37* in *Appendix 2*.

National (English) data are, however, available that cover all deaths associated with all the ICD-10 codes that make up each PBC. Therefore, it is possible to adjust the incomplete reporting of mortality at PCT level (see *Health outcome data* in *Appendix 2*) before applying the estimated outcome elasticities to calculate the deaths averted due to expenditure. Applying published estimates of YLL per death to all the deaths averted using coverage adjustment factors [as illustrated in column (3) of *Table 101*] provides the estimate of the cost per life-year reported in *Appendix 2*. Note that the proportionate effects on mortality (due to changes in expenditure) are therefore assumed to be similar for mortality that is and is not recorded at PCT level. This seems more reasonable than assuming no effect of expenditure on mortality that happens not to be recorded at PCT level.

The published estimates of YLL (NHS IC) used in *Chapter 3* only include deaths that occurred before the age of 75 years (but exclude deaths before age 1 year) and are based on the difference between age 75 years and the age of each death before 75 years. These estimates have the same limited coverage as PCT-level mortality data, so are not available for all the ICD-10 codes that make up each PBC. Therefore, applying the available estimates of YLL per death to the estimated number of deaths averted requires an assumption that the YLL per death is similar for those groups of ICD-10 codes covered and not covered by the published YLL figures.

This can be examined by using national ONS data to calculate YLL in the same way as NHS IC, but with full coverage of all the ICD-10 codes that make up each PBC. Although ONS data provides complete coverage and reports gender, age at death is only reported in 5-year ranges (these data are not available at PCT level so could not be used when estimating outcome elasticities in *Chapter 3*). Therefore, using ONS data to estimate YLL requires taking the mid-point[a] of each range as the age of death (i.e. assuming reported deaths are equally likely over the range in which they are reported). For this reason it is not possible to precisely recover the published YLL figures using ONS data for those ICD-10 code groupings that can be precisely matched to the NHS IC coverage. However, the differences are small (ranging from −1% to 2% as shown in *Table 102*), suggesting that taking the mid-point of each range as the age of death is a reasonable approximation.

Published estimates of YLL are available from the NHS IC for PBC 16 (trauma and injuries), but ONS does not provide the information required to calculate YLL for this PBC. The estimated outcome elasticity for PBC 16 (trauma and injuries) was zero for 2006 and could not be estimated for 2008 expenditure. Therefore, this PBC does not contribute any changes in health outcomes, although the changes in this expenditure are included in subsequent estimates of cost per life-year and QALY thresholds. However, there was very limited coverage of mortality data recorded at PCT level and the expenditure data for this PBC. In addition, the mortality data that was available (ICD-10 codes S72, S02, S06 and T90) was less likely to be

TABLE 102 Estimates of YLL for NHS IC and ONS for those ICD-10 code groupings that can be precisely matched to the NHS IC coverage

PBC		(1) $YLL_{<75}$ (NHS IC)[a]	(2) $YLL_{<75}$ (ONS)[b]	(3) Difference in YLL (%)
1	Infectious diseases	35,517	35,688	0.5
2	Cancer	735,674	744,240	1
4	Endocrine problems	19,224	19,445	1
10	Circulatory	453,878	461,062	2
18 + 19	Maternity and neonates	164,200	163,105	−1

a Does not take into account coverage adjustment.
b Deaths at age < 1 year included in PBC 18 + 19.

associated with changes expenditure in this PBC and more likely to be associated with changes in expenditure in others. Consequently, the health effects of changes in expenditure in PBC 16 may be underestimated. Therefore, this PBC does not contribute any changes in health outcomes due to changes in expenditure in subsequent estimates of cost per life-year and QALY thresholds.

The differences between estimates of YLL based on ONS and NHS IC data are, however, much more significant and are reported in *Table 103*. These reflect differences in the distribution of ages at death between those groups of ICD-10 codes covered and not covered in the NHS IC figures. For example, NHS IC figures available at PCT level for PBC 7 (neurological problems) have low coverage of all deaths in this PBC [0.136 in *Table 103*, column (1)]. The deaths that are reported in NHS IC are associated with epilepsy and the YLL [22,046 in *Table 103*, column (2)] reflects the generally younger age at death in this group. When adjusted for full coverage [22,046/0.136 = 162,100 in *Table 103*, column (3)], the estimated YLL is much greater than the YLL based directly on all deaths by age group reported for the PBC in ONS. This difference in YLL reflects the fact that the deaths in PBC 7 which are not covered by NHS IC figures tend to be in older age groups so generate fewer YLL.

Using ONS data also allows deaths under the age of 1 year to be appropriately assigned to PBCs via the ICD-10 code in which they occurred (NHS IC YLL figures exclude deaths under 1 year), rather than assigning them all to PBC 18 + 19 as in *Appendix 2*.[b] This explains the large reduction in YLL for PBC 18 + 19 (maternity and neonates) as much of the mortality is reassigned to ICD-10 codes which contribute to other PBCs. As most of the deaths that are reassigned are allocated to PBC 1 (infectious diseases) the YLL for this PBC increases despite complete reporting of deaths at PCT level and full coverage by NHS IC figures (*Table 104*).

Using ONS data to calculate YLL in the same way as the published NHS IC figures, but overcoming some of the issues associated with the reporting of mortality at PCT level and the coverage of published estimates of YLL, generates similar estimates of a cost per life-year threshold [see column (2) in *Table 106*] to those reported in *Appendix 2*.

Life expectancy and years of life lost

As noted above, the NHS IC estimates of YLL only include deaths below 75 years and are based on the difference between age 75 years and the age of each death below 75 years. Implicitly, this treats 75 years as the appropriate normal LE for males and females for the population at risk in each PBC. However, with the exception of maternity and neonates, most deaths in PBCs occur above the age of 75 years and

TABLE 103 Estimates of YLL for NHS IC and ONS

PBC		(1) Coverage of mortality data relative to spend data	(2) $YLL_{<75}$ (NHS IC)	(3) $YLL_{<75}$ adjusted (NHS IC)	(4) $YLL_{<75}$ no adjustment needed (ONS)	(5) Difference from adjusted NHS IC to ONS (%)
1	Infectious diseases	1.000	35,517	35,517	40,928	15
2	Cancer	0.984	735,674	747,636	758,804	1
4	Endocrine problems	0.634	19,224	30,322	41,548	37
7	Neurological problems	0.136	22,046	162,100	93,755	–42
10	Circulatory	0.992	453,878	457,538	481,246	5
11	Respiratory	0.773	108,074	139,812	147,465	6
13	Gastrointestinal	0.571	115,303	201,931	177,532	–12
17	Genitourinary	0.172	3343	19,438	17,380	–11
18 + 19	Maternity and neonates	0.679	164,200	241,826	15,409	–94

TABLE 104 Estimates of YLL for NHS IC and ONS including deaths age < 1 year

PBC		(1) $YLL_{<75}$ (NHS IC)	(2) $YLL_{<75}$ (ONS)[a]	(3) Difference in YLL (%)
1	Infectious diseases	35,517	40,928	15
2	Cancer	735,674	744,960	1
4	Endocrine	19,224	19,445	1
10	Circulatory	453,878	464,763	2
18 + 19	Maternity and neonates	164,200	15,409[b]	–91

a Deaths age < 1 year included in PBC of death.
b Does not include YLL from deaths < 28 days.

LEs are significantly greater than 75 years. Based on 2006–8 data, LE at birth is greater than 75 years (77.74 years for males and 81.88 years for females).[c] Given the need to reflect the normal LE for the at risk population, it is more appropriate to use the age distribution of the general population, and calculate LE conditional on age averaged over the general population's age distribution. General population LEs are estimated to be 80.7 years for males and 84.4 years for females. These LE estimates will always be higher than LEs at birth.

Based on ONS data, YLL can be recalculated using the above estimates of gender-specific LE for the general population. When increasing LE two effects occur, both of which tend to increase estimates of YLL. First, more deaths are included in the YLL calculation (those that occur between age 75 years and LE) and second, each death previously counted below 75 years will generate 5.7 or 9.4 more YLL for males and females respectively. The effect on the number of deaths and the YLL for each PBC using the LE of the general population is reported in *Table 106*.

The number of deaths counted below LE increases for every PBC except for maternity and neonates because, as expected, all deaths are below age 75 years in PBC 18 + 19. However, YLL increases for all PBCs reflecting the additional years otherwise expected to be lived to an older LE. Of course including more of the deaths observed in each PBC and the greater YLL associated with them will generate more deaths averted and more YLGs when applying the same proportionate effects from the outcome elasticities estimated in *Appendix 2*. Therefore, the cost per death averted and cost per life-year thresholds are expected to be lower using these figures than those reported in *Appendix 2*.

TABLE 105 Summary of cost per death averted and cost per life-year threshold

	Using 75 years as the cut-off (ONS)		Using LE as the cut-off (ONS)	
PBC scenario	(1) Cost per death averted (£)	(2) Cost per LY gained (£)	(3) Cost per death averted (£)	(4) Cost per YLG (£)
All big four programmes	122,756	10,398	63,426	5487
11 PBCs (with mortality)	240,433	20,031	124,655	10,660
All 23 PBCs (zero health effects for remaining 12 PBCs)	884,579	73,697	458,620	39,218
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	271,739	22,639	140,886	12,048

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

TABLE 106 The difference in YLL by LE

PBC		(1) $Deaths_{<75}$ (ONS)	(2) $Deaths_{<LE}$ (ONS)	(3) Difference in deaths due to increased LE (%)	(4) $YLL_{<75}$ (ONS)	(5) $YLL_{<LE}$ (ONS)	(6) Difference in YLL due to increased LE (%)
1	Infectious diseases	2050	3710	81	40,928	62,051	52
2	Cancer	62,944	95,212	51	758,804	1,345,013	77
4	Endocrine	2367	4000	69	41,548	65,015	56
7	Neurological	5095	8975	76	93,755	145,526	55
10	Circulatory	41,487	82,098	98	481,246	916,170	90
11	Respiratory	14,000	30,500	118	147,465	310,326	110
13	Gastrointestinal	10,611	15,827	49	177,532	273,303	54
17	Genitourinary	1588	4197	164	17,380	39,098	125
18 + 19	Maternity and neonates	226	226	0	15,409	17,167	11

LE: male = 80.7 years, female = 84.4 years.

The impact on the cost per life-year and cost per death averted thresholds is summarised in *Table 105*. A detailed breakdown of the changes in spend and YLL across PBCs is presented in *Table 107*. A listing of the spend and outcome elasticities used in threshold calculations throughout this section is in *Table 108* [see columns (2) and (5)]. Note that in the analyses in *Appendix 2* and sections in this appendix up to *Using ratios of quality-adjusted life-years to years of life lost* (corresponding *to Chapter 3* and *Chapter 4*, *From mortality to life-years*, *Adjusting life-years for quality-of-life* and *Using ratios of quality-adjusted life-years to years of life lost* in main report), expenditure elasticities were not estimated for the other 11 PBCs where outcome elasticities could not be estimated because the same health effect of changes in expenditure was assumed, i.e. it did not matter how changes in expenditure were allocated between them. However, in this section it does matter how the remaining change in expenditure is allocated.

The cost per death averted (or life saved) threshold should not be overinterpreted because this is of little direct policy interest as lives are never saved (death is only delayed), and the significance of a death averted depends critically on how long it is averted and the QoL in which additional years are lived (see *Adjusting life-years for quality-of-life*). However, establishing the number of deaths averted which are associated with net YLL is useful because it enables an assessment of the number of YLGs associated with each death averted. *Table 109* presents the YLL saved for each death averted implied by the assumptions underlying calculations of the cost per life-year threshold in *Table 107*. For the 11 PBCs with a mortality signal, each death averted is assumed to be associated with a gain of 11.7 YLL [when LE is used, see *Table 109*, column (2)]. This value is smaller than when using 75 years old as a cut-off [see *Table 109*, column (1)] because a higher proportion of deaths closer to the cut-off age are being considered (i.e. with lower YLL associated).

There are good reasons why YLL figures calculated as the difference between age of death and LE are likely to be overestimated. This is dealt with in the next section (see *Years of life lost and accounting for counterfactual deaths*). In *Inferring excess deaths* we take account of the fact that some of the deaths observed in a PBC would have occurred anyway in a similar 'normal' population (i.e. the counterfactual population not at risk through membership of the PBC), so not all observed deaths are 'excess' and generate YLL.

Years of life lost and accounting for counterfactual deaths

The estimates of YLL based on ONS data overcome many of the limitations of the published NHS IC figures. However, the YLL reported in *Table 106* are calculated in the same way as the NHS IC figures, by taking the difference between a fixed LE and the age at death for deaths observed below that LE. Simply taking the difference between a fixed LE and the age at death of deaths that occur below LE and ignoring those deaths that occur above LE, is only an accurate representation of the YLL if it is reasonable to assume that no deaths would have otherwise occurred prior to LE (so all 'normal' deaths must occur at LE) and that there are no deaths (survivors) beyond LE in the at risk population (i.e. all deaths below LE are excess deaths and there are no excess deaths above LE). The estimate of YLL in the previous section may thus be biased for two reasons: (i) it does not account for the fact that not all deaths observed below LE are 'excess' deaths in the sense that some deaths would have occurred (at the same age) in a similar population not at risk in the PBC; and (ii) some of the deaths observed above LE may be 'excess' deaths that would not otherwise have occurred at that age (see breakdown of deaths below and above LE in *Table 110*).

The overall effect on YLL, and on the cost per life-year, will depend on the number of deaths above and below LE that are excess. However, it is more likely that deaths below LE are 'excess'. Estimates of YLL are required which take account of the 'counterfactual' deaths that would have occurred even if the population in the PBC was not at risk through membership of the ICD-10 codes that make it up, but faced the same mortality risks as the general population, accounting for the age and gender distribution of the PBC population.

Ideally, with reliable information about the size of the population at risk in each PBC, and its age and gender distribution, it would be possible to estimate the number of deaths that would be expected to occur had this population not been at risk, based on mortality data for the general population. The difference between deaths observed across all ages in the PBC and the deaths expected to have occurred in this matched 'normal' population would provide the number of 'excess' deaths by age and gender. These 'counterfactual' deaths will occur in the other PBCs insofar as all deaths are recorded in an ICD-10 code, taking account of the unavoidable fact that everyone must die of something at some time. For example, even if all observed cancer mortality was avoidable and could in principle be eliminated with sufficient expenditure, lives would not be 'saved' but deaths delayed and reallocated to other causes.[d]

The YLL associated with each of these excess deaths is the LE conditional on gender and on surviving to the age at which the excess death occurred. The total YLL for the at risk population is simply the sum of these YLL over all excess deaths, which could occur at any age. We do not (and will never) know the counterfactual expected age of death for each individual patient. However, two perfectly matched populations of individuals, one at risk and another not at risk in the PBC can be compared in terms of their survival curves (*Figure 46*). The area below each survival curve reflects the LE and the area between the two survival curves returns the YLL. This is equivalent to comparing the average age of death across patients in the population at risk in the PBC (N patients), with the average age of death in the matched, not at risk, population (for simplicity assumed to be equally sized). *Equation 22* describes the YLL per patient as the difference in the average age of death, age_{death}, observed for each individual, i (out of N individuals), in each population. The YLL for the population is simply the per patient YLL multiplied by the size of the population N.

$$YLL_{per\ patient} = LE^{norm} - LE^{PBC} = \frac{1}{N}\sum_{i=1}^{N} age^{norm}_{death,\,i} - \frac{1}{N}\sum_{i=1}^{N} age^{PBC}_{death,\,i}$$
$$YLL = N \times YLL_{per\ patient} \qquad (22)$$

The difficultly is that routinely available data do not provide any information about the size of the population at risk or its age and gender distribution (matching criteria). Thus, a matched population cannot be generated, and the area between the two curves cannot be evaluated. Therefore, it is not possible to directly estimate excess deaths or compare survival curves. Even if the size of the at risk population is unknown we can still use information that might be available about its age and gender distribution (or make reasonable assumptions) to estimate a matched 'normal' LE using life tables for the

TABLE 107 Breakdown of the cost per death averted and cost per life-year thresholds

PBC		Change in spend (£M)	Using 75 years as the cut-off (ONS)			
			Deaths	Change in death	Cost per death averted (£)	YLL
2	Cancer	19	62,944	100.10	191,500	758,804
10	Circulatory	33	41,487	321.26	103,560	481,246
11	Respiratory	22	14,000	249.25	89,482	147,465
13	Gastrointestinal	17	10,611	72.69	227,013	177,532
All big four programmes					*122,756*	
1	Infectious diseases	8	2050	0.76	10,936,680	40,928
4	Endocrine	18	2367	18.99	929,559	41,548
7	Neurological	17	5095	3.52	4,889,114	93,755
17	Genitourinary	32	1588	0.74	42,993,075	17,380
16	Trauma and injuries	10	N/A	0.00	N/A	N/A
18 + 19	Maternity and neonates	8	226	0.24	32,813,038	15,409
First 11 PBCs					*240,433*	
3	Disorders of blood	11		46.57	240,433	
5	Mental health	204		849.17	240,433	
6	Learning disability	31		128.05	240,433	
8	Vision	24		100.54	240,433	
9	Hearing	6		26.60	240,433	
12	Dental	23		97.72	240,433	
14	Skin	11		43.72	240,433	
15	Musculoskeletal	15		62.93	240,433	
20	Poisoning and adverse events	4		18.27	240,433	
21	Healthy individuals	18		76.27	240,433	
22	Social care needs	68		281.19	240,433	
23	Other	78		0	N/A	
All (23 PBCs)					*271,739*	

N/A, not applicable.
We have been unable to obtain a satisfactory outcome model for trauma and injuries and have assumed a zero outcome elasticity.
For expenditure in 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.

		Using LE as the cut-off (ONS)					
Change in YLL	Cost per YLG (£)	Deaths	Change in deaths	Cost per death averted (£)	YLL	Change in YLL	Cost per YLG (£)
1207	15,885	95,212	151.42	126,599	1,345,013	2139	8962
3727	8928	82,098	635.73	52,333	916,170	7094	4690
2625	8495	30,500	543.00	41,074	310,326	5525	4037
1216	13,568	15,827	108.42	152,198	273,303	1872	8814
	10,398			*63,426*			*5487*
15	547,796	3710	1.38	6,043,179	62,051	23	361,319
333	52,957	4000	32.10	550,066	65,015	522	33,842
65	265,693	8975	6.19	2,775,491	145,526	100	171,172
8	3,928,251	4197	1.95	16,267,096	39,098	18	1,746,202
0	N/A	N/A	0	N/A	N/A	0	N/A
17	481,261	226	0.24	32,813,038	17,167	19	431,977
	20,031			*124,655*			*10,660*
559	20,031		89.83	124,655		1050	10,660
10,193	20,031		1637.87	124,655		19,153	10,660
1537	20,031		246.98	124,655		2888	10,660
1207	20,031		193.92	124,655		2268	10,660
319	20,031		51.30	124,655		600	10,660
1173	20,031		188.48	124,655		2204	10,660
525	20,031		84.34	124,655		986	10,660
755	20,031		121.38	124,655		1419	10,660
219	20,031		35.23	124,655		412	10,660
915	20,031		147.10	124,655		1720	10,660
3375	20,031		542.35	124,655		6342	10,660
	N/A			N/A			N/A
	22,639			*140,886*			*12,048*

TABLE 108 Outcome and spend elasticities

PBC		(1) Total spend 2006/7 (£M)	Spend elasticities			Change in spend, £M (% share)		(7) Outcome elasticities[b]
			(2) Unadjusted[a]	(3) Analysis up to *Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* (and *Appendix 3*)	(4) Analysis in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* (and *Appendix 3*)	(5) Analysis up to *Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* (and *Appendix 3*)	(6) Analysis in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* (and *Appendix 3*)	
2	Cancer	4122	0.465	0.465	0.657	19 (2.8)	27 (4)	0.342
10	Circulatory	6161	0.540	0.540	0.763	33 (4.9)	47 (6.9)	1.434
11	Respiratory	3285	0.679	0.679	0.959	22 (3.3)	32 (4.6)	2.622
13	Gastrointestinal	3700	0.446	0.446	0.630	17 (2.4)	23 (3.4)	1.536
All big four programmes		*17,268*				*91 (13.4)*	*129 (19)*	
1	Infectious diseases	1054	0.792	0.792	1.119	8 (1.2)	12 (1.7)	0.047
4	Endocrine	1853	0.953	0.953	1.346	18 (2.6)	25 (3.7)	0.842
7	Neurological	2790	0.616	0.616	0.870	17 (2.5)	24 (3.6)	0.112
17	Genitourinary	3482	0.912	0.912	1.289	32 (4.7)	45 (6.6)	0.051
16	Trauma and injuries	2892	0.358	0.358	0.506	10 (1.5)	15 (2.2)	–
18 + 19	Maternity and neonates	3574	0.224	0.224	0.316	8 (1.2)	11 (1.7)	0.482
First 11 PBCs		*32,912*				*185 (27.2)*	*261 (38.4)*	
3	Blood	837	0.700	1.338	0.989	11 (1.6)	8 (1.2)	–
5	Mental health	8406	1.271	2.429	1.796	204 (30.1)	151 (22.2)	–
6	Learning disability	2441	0.660	1.261	0.933	31 (4.5)	23 (3.4)	–
8	Vision	1362	0.929	1.775	1.313	24 (3.6)	18 (2.6)	–
9	Hearing	314	1.067	2.039	1.508	6 (0.9)	5 (0.7)	–

PBC		(1) Total spend 2006/7 (£M)	Spend elasticities			Change in spend, £M (% share)		(7) Outcome elasticities[b]
			(2) Unadjusted[a]	(3) Analysis up to *Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* (and *Appendix 3*)	(4) Analysis in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* (and *Appendix 3*)	(5) Analysis up to *Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* (and *Appendix 3*)	(6) Analysis in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* (and *Appendix 3*)	
12	Dental	2621	0.469	0.896	0.663	23 (3.5)	17 (2.6)	–
14	Skin	1429	0.385	0.736	0.544	11 (1.5)	8 (1.1)	–
15	Musculoskeletal	3369	0.235	0.449	0.332	15 (2.2)	11 (1.6)	–
20	Poisoning and adverse events	737	0.312	0.596	0.441	4 (0.6)	3 (0.5)	–
21	Healthy individuals	1355	0.708	1.353	1.000	18 (2.7)	14 (2.0)	–
22	Social care needs	1529	2.314	4.422	3.269	68 (10.0)	50 (7.4)	–
23	Other	10,585	0.739	0.739	1.044	78 (11.5)	111 (16.3)	–
All 23 PBCs		*67,896*				*679 (100)*	*679 (100)*	

a The spend elasticities reflect how a 1% increase in budget is distributed across PBCs; however, in the econometrics, these were estimated separately for each PBC [unadjusted estimates in column (4)] and because of this, its direct application to spend generates a change in budget bigger than the 1%. An adjustment was thus applied to the remaining 12 PBCs (except PBC 23 that was left unchanged), by multiplying each by a common factor – the magnitude of the unadjusted spend elasticities is changed but proportionality to the original elasticities is maintained.

b Without the negative sign.

TABLE 109 Implied YLL per death averted for each PBC

PBC		(1) Implied YLL per death averted (< 75 years)	(2) Implied YLL per death averted (< LE)
2	Cancer	12.1	14.1
10	Circulatory problems	11.6	11.2
11	Respiratory problems	10.5	10.2
13	Gastrointestinal problems	16.7	17.3
All big four programmes		*11.8*	*11.6*
1	Infectious diseases	20.0	16.7
4	Endocrine problems	17.6	16.3
7	Neurological problems	18.4	16.2
17	Genitourinary problems	10.9	9.3
16	Trauma and injuries	N/A	N/A
18 + 19	Maternity and neonates	68.2	76.0
First 11 PBCs		*12.0*	*11.7*

N/A, not applicable.

TABLE 110 Number of deaths below and above LE in 2006/7/8, by PBC

PBC		(1) < LE 2006	(2) > LE 2006	(3) < LE 2007	(4) > LE 2007	(5) < LE 2008	(6) > LE 2008	(7) Annual deaths < LE	(8) Annual deaths > LE
1	Infectious diseases	3824	3420	3902	3735	3403	2589	3710	3248
2	Cancer	95,549	34,192	95,331	35,455	94,758	37,144	95,213	35,597
4	Endocrine	4006	2661	3967	2750	4028	2882	4000	2764
7	Neurological	8454	5762	8845	6501	9626	6871	8975	6378
10	Circulatory	84,909	78,369	80,610	78,481	80,779	76,407	82,099	77,752
11	Respiratory	29,925	34,549	29,540	35,060	32,036	35,227	30,500	34,945
13	Gastrointestinal	15,893	8311	15,658	8376	15,930	8274	15,827	8320
17	Genitourinary	4056	6049	4072	6558	4465	6673	4198	6427
18 + 19	Maternity and neonates	195	0	216	0	267	0	226	0

LE: male = 80.7 years, female = 84.4 years.

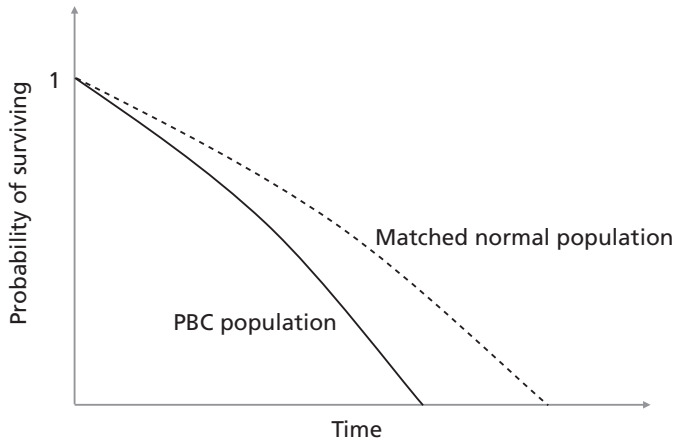


FIGURE 46 Survival curve of a population at risk in a PBC and of a matched 'normal' population.

general population – such a LE summarises the area under the counterfactual survival curve ($LE^{\text{norm}} = \frac{1}{N}\sum_{i=1}^{N} \text{age}^{\text{norm}}_{death,\,i}$ in *Equation 22*). Unfortunately, it is not possible to also calculate the LE for the population at risk in the PBC (or represent the survival curve) without information about the size of the at risk population – if it was possible, the difference between these life expectancies would approximate the YLL per patient at risk in a PBC.

Fortunately, we can still recover a consistent estimate of YLL using the normal LE of a matched population that is not at risk (a summary of the counterfactual average age of death), alongside the death data available for the PBC population. *Equation 23* shows that population YLL can be approximated by subtracting the age at which each observed death in a PBC has occurred to the normal LE.

$$\text{YLL} = \text{N} \times \left(\text{LE}^{\text{norm}} - \frac{1}{N}\sum_{i=1}^{\text{N}} \text{age}^{\text{PBC}}_{death,\,i}\right) = \sum_{i=1}^{\text{N}} \left(\text{LE}^{\text{norm}} - \text{age}^{\text{PBC}}_{death,\,i}\right) \tag{23}$$

The data on the PBC observed deaths available expresses the ages at which deaths occurred in age groups (k out of K groups). Following from *Equation 23*, the population YLL can be evaluated considering the number of patients dying in each of the age groups, $\text{N}_{\text{die},k}$, as depicted in *Equation 24*. This is equivalent to comparing survival curves where age is discretised into intervals and the mid-point of the intervals used as age of death – this is illustrated in *Figure 47*.

$$\text{YLL} = \sum_{k=1}^{K} \left(\text{LE}^{\text{norm}} - \text{age}_{death,\,k}\right) \times \text{N}_{\text{die},\,k} \tag{24}$$

The calculations (in *Equations 23* and *24*) require all observed deaths – both those that occur below and those that occur above this LE – to be taken into account. Those deaths occurring below LE generate YLL – compared with the average of a matched population not at risk. However, we must also account for those deaths that occur at ages above LE. These deaths generate life-years 'gained' compared with the average of a matched population not at risk. Therefore, the appropriate estimate is a net YLL (i.e. YLL – YLG). In effect, by subtracting YLG from YLL we take account of the fact that not all deaths below LE are excess deaths but some deaths above LE are. Insofar as deaths above LE have been observed in a specific PBC, the net YLL estimate will always be lower than the estimate of YLL. Consequently, the estimates in *Years of life lost and accounting for counterfactual deaths* overestimate YLL and, hence, underestimate the cost per life-year threshold.

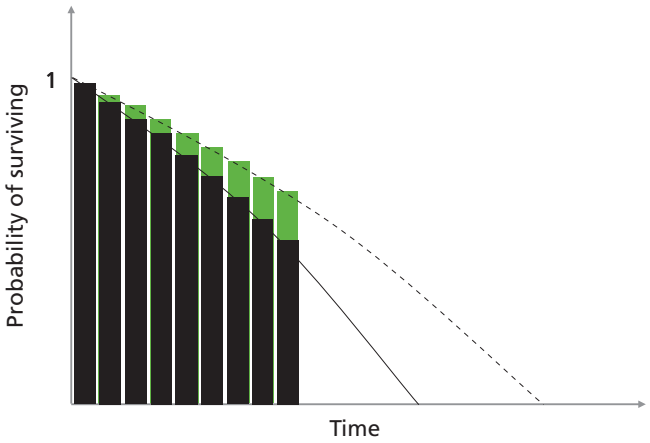


FIGURE 47 Area between the survival curves, discretised.

Using the life expectancy of the general population

Routinely available data provides the age and gender of observed deaths but no information about the age and gender distribution of the at risk population itself. Using observed age and gender at death [*Table 111*, column (3)] as an indication of the distribution of the at risk population will significantly overestimate the LE of a normal matched population insofar as a disease may be chronic (not all PBC mortality occurs on entry into the at risk population). If mortality risk increases over the disease duration, more deaths would be observed in groups that have been prevalent for some time (i.e. are older) than

TABLE 111 Average age (years) and LE (years) for PBCs based on age of the general population

PBC		Sex	(1) Average age of general population	(2) LE of general population	(3) Age at death	(4) LE at age of death
1	Infectious diseases	M	38.5	80.7	72.8	87.5
		F	40.8	84.4	79.3	91.1
2	Cancer	M	38.5	80.7	73.3	86.5
		F	40.8	84.4	73.8	88.8
4	Endocrine	M	38.5	80.7	72.5	87.1
		F	40.8	84.4	77.9	90.6
7	Neurological	M	38.5	80.7	72.8	87.2
		F	40.8	84.4	77.7	90.5
10	Circulatory	M	38.5	80.7	76.4	87.9
		F	40.8	84.4	82.7	91.7
11	Respiratory	M	38.5	80.7	79.4	89.0
		F	40.8	84.4	82.9	91.8
13	Gastrointestinal	M	38.5	80.7	68.9	85.7
		F	40.8	84.4	77.1	90.1
17	Genitourinary	M	38.5	80.7	81.6	90.1
		F	40.8	84.4	84.0	92.3
18 + 19	Maternity and neonates	M	38.5	80.7	1.1	78.3
		F	40.8	84.4	11.4	82.7

F, female; M, male.

those that are incident. Older age groups will thus be over-represented in observed deaths compared with a matched normal population. For these reasons LE and YLL would be overestimated using age at death as a proxy for the age distribution of the at risk population, and the cost per life-year would be underestimated.

In the absence of additional external information the net YLL could be based on the LE of the general population, reflecting its current age and gender distribution. Such net YLL estimates are reported in *Table 112*, and illustrate the impact of accounting for counterfactual deaths in the way described above. The YLL reported in column 5 of *Table 112* are calculated the same way and are the same as the figures previously reported [see column (5) of *Table 106*]. That is, they do not account for deaths that would have otherwise occurred below LE or the very many deaths that occur above LE. With the exception of PBC 18 + 19, many deaths occur above the LE of the general population [see column (4) in *Table 112*] in all PBCs. As a consequence, there are YLG associated with all other PBCs [see column (6)] so the net YLL in column (7) are lower than YLL based on the same LE. Therefore, failure to account for counterfactual deaths would lead to an overestimate of the YLL associated with a PBC and the effects of expenditure on YLL. The cost per life-year threshold would be underestimated (see *Table 115*).

However, these figures are only correct insofar as the distribution of age and gender in each PBC is similar to the general population. For example, if the at risk population tends to be younger the correct LE for the PBC will be lower. A lower LE will mean that there are less deaths below LE each generating fewer YLL, and more deaths above LE each generating more YLG. The net YLL will thus tend to be lower. Similarly, if the at risk population tends to be older than the general population, the correct LE will be higher and net YLL will also tend to be higher.

This explains the apparent net gain in YLL (negative net YLL) for PBC 17 (genitourinary) where most deaths occur at ages greater than the LE of the general population so that YLG exceeds YLL. As we are able to show later (see *Table 114*), this is because the age distribution in this PBC tends to be older than the general population (i.e. the LE for a matched normal population should be higher with fewer deaths above and more below this LE).

TABLE 112 Net YLL using LE of the general population

				Average 2006–8				
PBC		(1) LE of males (years)	(2) LE of females (years)	(3) Deaths < LE	(4) Deaths > LE	(5) YLL	(6) YLG	(7) Net YLL
1	Infectious diseases	80.7	84.4	3710	3248	62,052	18,796	43,256
2	Cancer	80.7	84.4	95,213	35,597	1,345,038	175,350	1,169,689
4	Endocrine	80.7	84.4	4000	2764	65,016	15,864	49,152
7	Neurological	80.7	84.4	8975	6378	145,529	34,621	110,908
10	Circulatory	80.7	84.4	82,099	77,752	916,192	444,694	471,498
11	Respiratory	80.7	84.4	30,500	34,945	310,334	215,829	94,505
13	Gastrointestinal	80.7	84.4	15,827	8320	273,308	45,295	228,012
17	Genitourinary	80.7	84.4	4198	6427	39,099	40,530	–1431
18 + 19	Maternity and neonates	80.7	84.4	226	0	17,167	0	17,167

Using additional information about age and gender distribution

It is evident that estimates of YLL require some account to be taken of counterfactual deaths. In the absence of routinely available information this requires examination of alternative sources of information which might provide a basis for more credible assumptions about the age and gender distribution of the at risk population in each PBC than either the distribution of observed deaths or of the general population.[e] The WHO GBD study, updated in 2008 using 2004 data (see *Addendum 1: data sources* for more details)[f] provides a range of summary health indicators for the UK, which are, in part, based on estimates of the incidence and duration of sequelae associated with different types of disease by age and gender. Therefore, the type of information used by the WHO in the GBD study to generate summary estimates for the UK can also be used to improve the assumptions required about the age and gender distribution of the PBC populations. Importantly, at this stage, we do not need to rely on estimates of the absolute size of the at risk population, but only the relative 'share' by age and gender.

Specifically, the information reported by the GBD study (estimates specific to the UK provided in the National Burden of Disease toolkit) reported the incidence and duration of sequelae associated with different types of disease by age and gender. As it is possible that a patient may experience more than one of the types of sequelae reported in the GBD study we use the gender and age distribution of the sequelae with the highest prevalence, i.e. the minimum estimate of prevalence consistent with these figures (see *Addendum 1: data sources*), to evaluate the age and gender distribution within each disease.

Global Burden of Disease classifies diseases by U-codes, which are groups of three-digit ICD-10 codes (see *Addendum 1: data sources* for details of how U-codes map to ICD-10 codes).[g] As we know which ICD-10 codes contribute to each PBC we can map information from U-codes to PBCs via the ICD-10 codes that contribute to each. The resulting average age and LE for each PBC is reported in columns (1) and (2) of *Table 113* using the information available from the GBD study in combination with life tables for the general population.

These summary estimates suggest that some of the PBC populations may be on average older than the general population (e.g. cancer, circulatory and genitourinary) or younger (e.g. maternity and neonates, infectious diseases and neurological). However, when trying to interpret these summaries it should be noted that the average age reported in *Table 113* is the average over the ages at which sequelae occur within the ICD-10 codes contributing to the PBC. Therefore, a similar average age can reflect very different age distributions. Some reflect a markedly bimodal distribution (e.g. PBC 11 respiratory), where there is high incidence at very young and older ages (*Figure 48*), or very different age distributions across the type of diseases that contribute to the PBC. For example, PBC 7 (neurological) includes dementia which accounts for the vast majority of the PBC population older than 70 years. However, a greater proportion of the population is in much younger age groups with other conditions, especially migraine (see *Addendum 1: data sources* for a detailed description of age and gender distributions in all PBCs). When interpreting these summary estimates it should also be noted that the reported LEs are not the LEs at the average ages reported in column (2) (see *Table 113*), but the average over the life expectancies for each age group within the contributing ICD-10 codes weighted by the age distribution of the sequelae with maximum prevalence from GBD U-codes.

The implications for net YLL of using these PBC specific estimates of 'normal' LE are reported in *Table 114*. As expected, the net YLL for those PBCs with a LE greater than the general population are higher than those reported in column (7) in *Table 112* (e.g. PBC 10 circulatory and PBC 17 genitourinary, which now has positive net YLL). Similarly, those PBCs with a LE less than the general population have lower net YLL than reported in column (7) in *Table 112* (e.g. PBC 1 infectious diseases and PBC 18 + 19 maternity and neonates, where the effect of a lower LE is more modest as there are no deaths above either of the estimates of LE).

The impact on the cost per life-year threshold of the issues discussed in this section is summarised in columns (3) and (4) of *Table 115*.

TABLE 113 Average age and LE for PBCs based on GBD

PBC		Sex	(1) Average age of general population (years)	(2) LE of general population (years)	(3) Proportion of males in PBC (GBD) (%)	(4) Average age in PBC (GBD) (years)	(5) Normal LE of PBC population (GBD) (years)
1	Infectious diseases	M	38.5	80.7	54.1	28.6	79.6
		F	40.8	84.4	45.9	30.2	83.6
2	Cancer	M	38.5	80.7	28.0	61.3	83.0
		F	40.8	84.4	72.0	52.3	84.7
4	Endocrine	M	38.5	80.7	38.4	44.2	81.0
		F	40.8	84.4	61.6	50.8	84.7
7	Neurological	M	38.5	80.7	28.1	24.8	79.6
		F	40.8	84.4	71.9	23.5	83.3
10	Circulatory	M	38.5	80.7	51.6	55.4	83.0
		F	40.8	84.4	48.4	57.9	86.5
11	Respiratory	M	38.5	80.7	48.0	32.1	80.3
		F	40.8	84.4	52.0	33.7	84.0
13	Gastrointestinal	M	38.5	80.7	42.9	35.8	80.6
		F	40.8	84.4	57.1	41.9	84.5
17	Genitourinary	M	38.5	80.7	85.9	63.2	83.5
		F	40.8	84.4	14.1	47.3	85.6
18 + 19	Maternity and neonates	M	38.5	80.7	16.3	3.0	78.7
		F	40.8	84.4	83.7	24.1	83.1

F, female; M, male.

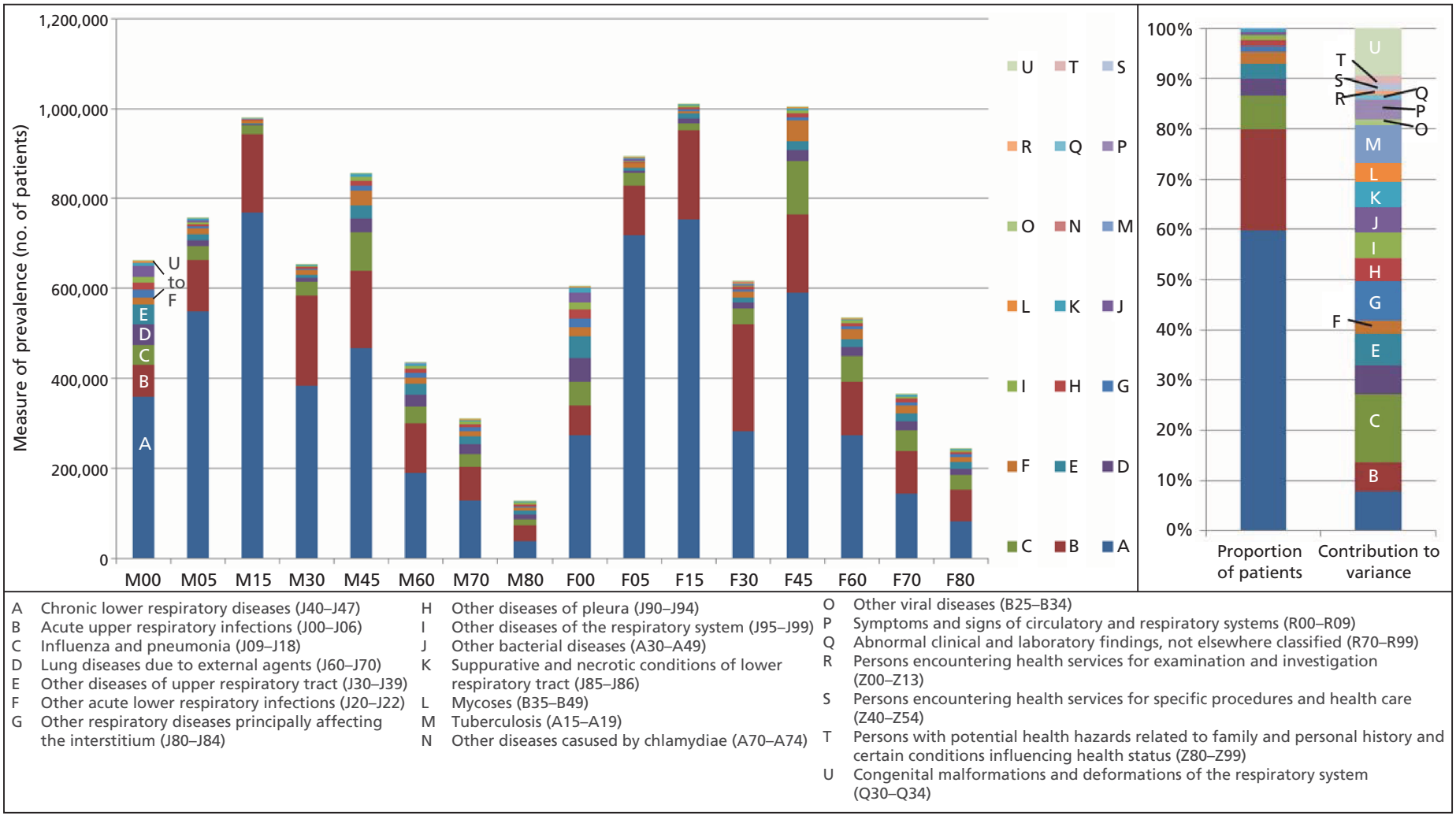


FIGURE 48 Distribution of PBC 11 prevalence by age, gender and contributing ICD-10 codes, alongside proportion of prevalent patients in the PBC and contribution to variance of each ICD-10 code.

TABLE 114 Net YLL using LE for each PBC

PBC		(1) LE of males	(2) LE of females	Average 2006–8 Deaths (3) < LE	(4) > LE	(5) YLL	(6) YLG	(7) Net YLL
1	Infectious diseases	79.6	83.6	3498	3460	58,686	21,724	36,962
2	Cancer	83.0	84.7	101,203	29,607	1,473,733	126,549	1,347,184
4	Endocrine	81.0	84.7	4068	2696	66,283	15,058	51,225
7	Neurological	79.6	83.3	8370	6983	135,686	41,770	93,917
10	Circulatory	83.0	86.5	96,694	63,157	1,102,020	278,251	823,768
11	Respiratory	80.3	84.0	29,549	35,897	298,343	230,313	68,030
13	Gastrointestinal	80.6	84.5	15,824	8323	273,117	45,414	227,703
17	Genitourinary	83.5	85.6	4969	5655	47,229	29,101	18,127
18 + 19	Maternity and neonates	78.7	83.1	226	0	16,801	0	16,801

TABLE 115 Summary of cost per life-year threshold

PBC scenario	Using cut-off in estimating YLL (ONS) (£) (1) Cut-off of 75 years	(2) Cut-off of LE of the general population	Using net YLL estimates (£) (3) Using LE of the general population	(4) Using LE of the PBC population (GBD)
All big four programmes	10,398	5487	10,421	8080
11 PBCs (with mortality)	20,031	10,660	19,928	15,628
All 23 PBCs (zero health effects for remaining 12 PBCs)	73,697	39,218	73,317	57,497
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	22,639	12,048	22,523	17,663

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

Taking account of counterfactual deaths by calculating net YLL based on the LE of the general population [see *Table 115*, column (3)] provides similar estimates to those reported in *Appendix 2*. Assuming that PBC populations have the same age and gender distribution as the general population when the, albeit limited, information that is available suggests otherwise, seems inappropriate. Therefore, our preferred central estimate of the cost per life-year threshold is reported in column (4) (see *Table 115*). These are lower than those based on the general population, reflecting the impact on net YLL of evidence that the population at risk in some key PBCs (especially PBCs 2 and 10) tend to be older than the general population. A detailed breakdown of the changes in spend and YLL across PBCs that originate this central estimate are presented in columns (5)–(7) of *Table 116*. In *Summary of cost per life-year estimates* we consider extreme upper and lower bounds that might be placed on this central estimate.

TABLE 116 Life-year threshold using net YLL estimates (non-zero health effects for remaining PBCs except GMS)

PBC		(1) Change in spend (£M)	Using LE of the general population			Using LE of the PBC population		
			(2) Net YLL	(3) Change in Net YLL	(4) Cost per YLG (£)	(5) Net YLL	(6) Change in Net YLL	(7) Cost per YLG (£)
2	Cancer	19	1,169,689	1860	10,305	1,347,184	2142	8947
10	Circulatory problems	33	471,498	3651	9112	823,768	6379	5216
11	Respiratory problems	22	94,505	1683	13,256	68,030	1211	18,415
13	Gastrointestinal problems	17	228,012	1562	10,564	227,703	1560	10,579
All big four programmes					*10,421*			*8080*
1	Infectious diseases	8	43,256	16	518,314	36,962	14	606,574
4	Endocrine problems	18	49,152	394	44,765	51,225	411	42,953
7	Neurological problems	17	110,908	77	224,601	93,917	65	265,235
17	Genitourinary problems	32	–1431	–1	–47,709,995	18,127	8	3,766,371
16	Trauma and injuries	10	N/A	0	N/A	N/A	0	N/A
18 + 19	Maternity and neonates	8	17,167	19	431,977	16,801	18	441,387
First 11 PBCs					*19,928*			*15,628*
3	Disorders of blood	11		562	19,928		716	15,628
5	Mental health disorders	204		10,245	19,928		13,064	15,628
6	Learning disability	31		1545	19,928		1970	15,628
8	Problems of vision	24		1213	19,928		1547	15,628
9	Problems of hearing	6		321	19,928		409	15,628
12	Dental problems	23		1179	19,928		1503	15,628

PBC		(1) Change in spend (£M)	Using LE of the general population			Using LE of the PBC population		
			(2) Net YLL	(3) Change in Net YLL	(4) Cost per YLG (£)	(5) Net YLL	(6) Change in Net YLL	(7) Cost per YLG (£)
14	Skin	11		528	19,928		673	15,628
15	Musculoskeletal system	15		759	19,928		968	15,628
20	Poisoning and adverse events	4		220	19,928		281	15,628
21	Healthy individuals	18		920	19,928		1173	15,628
22	Social care needs	68		3393	19,928		4326	15,628
23	Other	78		0	N/A		0	N/A
All (23 PBCs)					*22,523*			*17,663*

N/A, not applicable.
We have been unable to obtain a satisfactory outcome model for trauma and injuries and have assumed a zero outcome elasticity.
For expenditure in 2006/7, the neonate category has been merged with maternity to obtain plausible outcome and expenditure models.

Inferring excess deaths

We have been able to establish a measure of net YLL which takes account of deaths that would have occurred anyway below a normal LE for the PBC population (i.e. not all deaths observed in a PBC are excess), and that some deaths observed above this LE would not otherwise have occurred at that age (i.e. some of these deaths are excess). As explained in *Years of life lost and accounting for counterfactual deaths*, net YLL calculated in this way is equivalent to first establishing the number of excess deaths at each age, then calculating YLL for each excess death (based on the LE conditional on the age at which each excess death occurred) and then summing these YLL across all excess deaths (i.e. across all ages). In other words, the estimates of net YLL imply a number of excess deaths required to generate them in each PBC. Therefore, it is possible to solve for the total number of excess deaths based on the net YLL and the average YLL per observed death (the average of the sum of the YLL for every observed death where the YLL for each observed death is the difference between age at death and LE conditional on age of death). The net YLL divided by the average YLL per death provides the number of excess deaths required, which on average will generate the estimated net YLL.

In the absence of information about the age distribution of excess deaths, calculations assume that the average YLL associated with observed and excess deaths are similar. Insofar as excess deaths are thought likely to generate more YLL than observed deaths the number of excess deaths will tend to be overestimated. This would tend to underestimate the cost per excess death averted. However, the cost per life-year estimates remain unchanged and do not require such an assumption.

The implied excess deaths associated with net YLL based on the LE of the PBCs [see *Table 114*, column (7)] are reported in *Table 117*. With the exception of PBC 18 + 19, excess deaths are some proportion of total observed deaths in each PBC. The proportion of excess deaths differs by PBC reflecting the distribution of deaths relative to the LE of the PBC. For example, in those PBCs where a large proportion of deaths occur below LE [see *Table 117*, columns (3) and (4)], excess deaths tend to be a greater proportion of total deaths (e.g. PBCs 2, 13 and 10). Where most deaths occur above LE, excess deaths as a proportion of total deaths tend to be lower (e.g. PBCs 11, 17 and 1). Nevertheless, the impact of the age distribution of deaths and the age distribution of the at risk population (summarised as LE) on the calculation of excess deaths is not always obvious as both will affect the numerator (net YLL) as well the denominator (average YLL per death) in this calculation.

TABLE 117 Excess deaths implied by net YLL

PBC		(1) Net YLL	(2) YLL per observed death	(3) Excess deaths	(4) Total deaths	(5) % excess deaths
1	Infectious diseases	36,962	13.4	2797	6958	40
2	Cancer	1,347,184	14.1	95,715	130,810	73
4	Endocrine	51,225	13.7	3769	6764	56
7	Neurological	93,917	13.7	6909	15,353	45
10	Circulatory	823,768	10.5	79,218	159,851	50
11	Respiratory	68,030	9.2	7386	65,445	11
13	Gastrointestinal	227,703	15.2	15,199	24,147	63
17	Genitourinary	18,127	8.3	2172	10,625	20
18 + 19	Maternity and neonates[a]	16,801	73.9	226	226	100

a The number of excess deaths estimated in PBC 18 + 19 was initially estimated to be 230, higher than the number of total deaths. This is due to the use of approximations (i.e. in the LE, or in using the net YLL), thus, for consistency, we assumed this to be 100% of the total deaths.

Excess deaths are calculated for each gender by dividing net YLL by the YLL per death [column (5) = column (3)/column (4)].

Estimates of net YLL and changes in life-years due to expenditure (see *Tables 114* and *115*) have already accounted for the fact that not all deaths are excess and do not generate YLL. Nevertheless, solving for the number of implied excess deaths associated with these net YLL estimates allows a comparison of the cost per excess and observed PBC death avoided, and an examination of the interpretation that can be placed of the life-years expected to be gained from an excess or observed death averted.

As only deaths observed in the PBC can be used to estimate the effects of expenditure (excess deaths are not directly observed as they rely on an unobserved counterfactual population and would occur outside the PBC), the outcome elasticities can be interpreted as the proportionate change in observed PBC mortality due to a proportionate change in PBC expenditure. Equally, however, they can also be interpreted as the proportionate effect on excess death due to a proportionate change in expenditure so can be applied to either total observed or total excess deaths. Observed PBC mortality that is sensitive to changes in expenditure can be regarded as 'avoidable' and it is only this mortality that contributes to the estimates of outcome elasticities (not all observed mortality is necessarily avoidable and sensitive to expenditure – such mortality will not contribute to the estimates). Not all observed mortality is excess when compared with the counterfactual population, but this is unrelated to the question of how sensitive it is to expenditure (i.e. observed mortality will be just as sensitive to expenditure whether or not it is regarded as excess). Therefore, the estimated outcome elasticities can be applied to either observed PBC deaths or excess PBC deaths.

The cost per excess death and the cost per PBC death averted are reported in *Table 118*, and a detailed breakdown of changes in spend and excess or total deaths across PBCs is shown in *Table 119*. The cost per PBC death averted is, of course, significantly lower than the cost per excess death as excess deaths are only a proportion of total deaths (see *Table 117*). Also, the costs per PBC death averted are substantially lower than those reported in *Appendix 2* (see *Tables 68* and *69*), as these estimates do not restrict the effects of expenditure to PBC deaths under 75 years of age.

Recall from *Appendix 2* that the measure of mortality that is available at PCT level and used to estimate the outcome elasticities is restricted to deaths under 75 years of age, as are the published estimates of YLL associated with them (see *Mortality and years of life lost*). However, to restrict effects only to those aged under 75 years would imply that there is no excess mortality above 75 years of age or equivalently that there are no health effects of PBC expenditure above 75 years of age. Rather than assume no effects of NHS activity in older populations, we apply the effects that can be observed to the whole PBC but account for deaths that would have otherwise occurred in our estimate of net YLL in *Years of life lost and accounting for counterfactual deaths*. *Table 120* illustrates the number deaths averted for a 1% change in budget implicit in the alternative calculations of the cost per death averted threshold.

In many respects, whether or not PBC deaths at older ages are as sensitive to changes in expenditure is not critical, as any observed deaths that might be averted at older ages are less likely to generate YLGs because they are more likely to have occurred anyway in that year (i.e. are excess so generate

TABLE 118 Summary of the cost per death averted threshold

PBC scenario	(1) Cost per excess death averted (£)	(2) Cost per PBC death averted (£)
All big four programmes	91,129	32,864
11 PBCs (with mortality)	177,692	64,774
All 23 PBCs (zero health effects for remaining 12 PBCs)	653,748	238,310
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	200,829	73,208

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

TABLE 119 Breakdown of the cost per death averted threshold

PBC		(1) Change in spend (£M)	PBC deaths			Excess deaths		
			(2) Total PBC deaths	(3) Change in PBC deaths	(4) Cost per PBC death averted (£)	(5) Excess deaths	(6) Change in excess deaths	(7) Cost per excess death averted (£)
2	Cancer	19	130,809	208.03	92,147	95,715	152.22	125,934
10	Circulatory problems	33	159,851	1237.82	26,878	79,218	613.43	54,235
11	Respiratory problems	22	65,446	1165.14	19,142	7386	131.49	169,616
13	Gastrointestinal problems	17	24,148	165.42	99,757	15,199	104.12	158,488
All big four programmes					*32,864*	*0*		*91,129*
1	Infectious diseases	8	6958	2.59	3,222,218	2797	1.04	8,014,595
4	Endocrine problems	18	6765	54.28	325,291	3769	30.24	583,830
7	Neurological problems	17	15,353	10.59	1,622,486	6909	4.77	3,605,579
17	Genitourinary problems	32	10,625	4.94	6,425,694	2172	1.01	31,430,287
16	Trauma and injuries	10	N/A	0.00	N/A	N/A	0.00	N/A
18 + 19	Maternity and neonates	8	226	0.24	32,813,038	226	0.24	32,813,038
First 11 PBCs					*64,774*			*177,691*
3	Disorders of blood	11		172.87	64,774		63.01	177,692
5	Mental health disorders	204		3152.02	64,774		1149.00	177,692
6	Learning disability	31		475.30	64,774		173.26	177,692
8	Problems of vision	24		373.19	64,774		136.04	177,692

PBC		(1) Change in spend (£M)	PBC deaths			Excess deaths		
			(2) Total PBC deaths	(3) Change in PBC deaths	(4) Cost per PBC death averted (£)	(5) Excess deaths	(6) Change in excess deaths	(7) Cost per excess death averted (£)
9	Problems of hearing	6		98.72	64,774		35.99	177,692
12	Dental problems	23		362.72	64,774		132.22	177,692
14	Skin	11		162.30	64,774		59.16	177,692
15	Musculoskeletal system	15		233.59	64,774		85.15	177,692
20	Poisoning and adverse events	4		67.80	64,774		24.71	177,692
21	Healthy individuals	18		283.09	64,774		103.19	177,692
22	Social care needs	68		1043.74	64,774		380.47	177,692
23	Other	78		0.00	0.00		0.00	N/A
All 23 PBCs					*73,208*			*200,828*

N/A, not applicable.

TABLE 120 Illustration of the number of deaths averted for a 1% change in budget

PBC scenario	Using deaths < 75 years (see *Appendix 2, Table 67*)		Using excess deaths (see *Table 118*)		Using PBC deaths (see *Table 118*)	
	(1) Cost per death averted (£)	(2) Number of deaths averted for a 1% change in budget	(3) Cost per excess death averted (£)	(4) Number of excess deaths averted for a 1% change in budget	(5) Cost per PBC death averted (£)	(6) Number of PBC deaths averted for a 1% change in budget
All big four programmes	137,188	665	91,129	1001	32,864	2776
11 PBCs (with mortality)	270,881	681	177,692	1039	64,774	2849
All 23 PBCs (zero health effects for remaining 12 PBCs)	996,655	681	653,748	1039	238,310	2849
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	306,153	2218	200, 828	3381	73,208	5191

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

TABLE 121 Implied YLL per death averted for each PBC

PBC		(1) Implied YLL per excess death averted	(2) Implied YLL per PBC death averted
2	Cancer	14.07	10.30
10	Circulatory problems	10.40	5.15
11	Respiratory problems	9.21	1.04
13	Gastrointestinal problems	14.98	9.43
All big four programmes		*11.28*	*4.07*
1	Infectious diseases	13.21	5.31
4	Endocrine problems	13.59	7.57
7	Neurological problems	13.59	6.12
17	Genitourinary problems	8.34	1.71
16	Trauma and injuries	N/A	N/A
18 + 19	Maternity and neonates	74.34	74.34
First 11 PBCs		*11.37*	*4.14*

N/A, not applicable.

zero YLGs anyway). Therefore, they will have very limited impact on cost per life-year or, subsequently, on cost per QALY estimates (in *Adjusting life-years for quality-of-life* and *Including quality-of-life effects during disease*). For this reason, it is the cost per life-year rather than cost per death averted, whether excess or observed, that is of primary interest. The cost per PBC or excess death averted (or life saved) should thus not be overinterpreted, as lives are never saved (death is only delayed). However, establishing the number of excess and PBC deaths averted which are associated with net YLL is useful because it enables an assessment of the number of YLGs associated with each death averted. These are reported for each PBC in *Table 121* and range from 74.3 years per excess death for PBC 18 + 19 maternity and neonates to 8.3 years per excess death for PBC 17 genitourinary. On average, across all 11 PBCs each excess death averted is associated with 11.4 YLGs.

However, clinicians or the evaluative literature cannot distinguish whether or not an observed death is excess. What can be observed is if groups of similar patients with and without access to a treatment survive and for how long. Therefore, it is the life-years associated with each observed death that provides a context that can be interpreted based on experience and evidence of how effective those interventions that could be invested or disinvested tend to be. The average life-years expected to be gained associated with each observed PBC death averted takes account of the fact that some deaths that are avoided in the PBC are not delayed for very long but quickly occur elsewhere and do not generate YLG (i.e. they were not excess deaths). The portion of observed deaths that are regarded as excess depend on how time is discretised. The data available report deaths in annual intervals so in this context ‘quickly’ means within 1 year. If deaths were reported in narrower time intervals then a greater proportion of observed deaths would be regarded as excess and, in the limit, with continuous time all observed deaths would be excess. Of course, the average YLL associated with them would be smaller and is approximated by the net YLL per observed death reported (the effect of approximation is likely to be small but unavoidable as it is due to deaths being reported in annual intervals).

The data available report deaths in annual intervals so in this context 'quickly' means within 1 year. If deaths were reported in narrower time intervals then a greater proportion of observed deaths would be regarded as excess and in the limit with continuous time all observed deaths would be excess. Of course, the average YLL associated with them would be smaller and is approximated by the net YLLs reported in *Table 12* per observed death (the effects of approximation is likely to be small but unavoidable as it is due to deaths being reported in annual intervals). These are also reported for each PBC in *Table 121* and range from 74.3 years per observed death for PBC 18 + 19 maternity and neonates[h] to 1.0 for PBC 11 respiratory problems, i.e. the YLL per PBC death are much lower for those PBCs where a small proportion of observed deaths are excess. On average across all 11 PBCs each PBC death averted is associated with 4.1 YLGs.

Summary of cost per life-year estimates

The sequence of analysis set out above has enabled an examination of the impact of the limitations associated with the incomplete reporting of mortality data at PCT level and incomplete coverage of published YLL estimates. We have also been able to consider effects above age 75 years while taking account of the fact that many deaths would have occurred anyway, despite the limited information available about the population at risk within a PBC. The GBD study does provide some information about the age and gender distribution of the population at risk in a PBC so offers some improvement over the other assumptions that would otherwise be required (i.e. that the distribution of age and gender is the same as the general population or follows the distribution of observed deaths). For this reason, the cost per life-year threshold in column (4) of *Table 115* and repeated in lines (1)–(4) in *Table 122* are regarded as the central or best estimates given the evidence available and the credibility of alternative assumptions that could be made. As explained in the *Introduction*, these are based on the conservative assumptions that any health effects of changes in expenditure are restricted to 1 year, which, to some extent, may be offset by the more optimistic assumption that any death averted returns the individual to the mortality risk faced by the general population, matched for age and gender.

It does not seem credible to imagine that NHS expenditure has no health effects in the 12 PBCs which do not have sufficient mortality reported at PCT level to estimate outcome elasticities – what is implied by the estimate reported in *Table 122*, line (3). Therefore, it is the estimates reported in lines (2) and (4) that are of policy interest. The estimate of £15,628 per life-year [see line (2)] is restricted to the effects of changes in expenditure in the 11 PBCs where outcome elasticities can be estimated. The threshold of £17,663 per life-year uses the estimated health effects of expenditure in these PBCs as a surrogate for health effects in the others, that is assuming that the effects that can be observed will be similar to those that cannot. However, no health effects are assigned to PBC 23 (GMS) on the basis that any health effects of this expenditure would be recorded in the other PBCs.

It would be inappropriate to assign all the change in GMS expenditure to the estimate of cost per life-year based only on the 11 PBCs with outcome elasticities as it would imply that GMS only contributes to these PBCs. Restricting attention to the 11 PBCs with outcome elasticities but allocating part of the change in GMS expenditure to them based on their proportional share of changes in overall expenditure would yield the same cost per life-year as reported in line (4).[i]

The extreme upper and lower bounds for the cost per life-year thresholds in *Table 122* are based on making the necessary assumptions about duration of health effects and how long a death might be averted optimistic (providing the lower bound for the threshold) or conservative (an upper bound for the threshold). The lower bound [see lines (5)–(8)] is based on assuming that health effects are not restricted to 1 year but apply to the whole of the remaining disease duration of the population at risk in PBCs during the expenditure year.

TABLE 122 Summary of the cost per life-year threshold with upper and lower bounds

PBC grouping	Cost per life-year threshold
Best estimate	
Effect of expenditure on mortality	1 year
YLL per PBC death averted	~4.1
(1) All big four programmes	£8080
(2) 11 PBCs (with mortality)	£15,628
(3) All 23 PBCs (zero health effects for remaining 12 PBCs)	£57,497
(4) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	£17,663
Lower bound	
Effect of expenditure on mortality	Remainder of disease
YLL per PBC death averted	~4.1
(5) All big four programmes	£386
(6) 11 PBCs (with mortality)	£6106
(7) All 23 PBCs (zero health effects for remaining 12 PBCs)	£22,463
(8) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	£6901
Upper bound	
Effect of expenditure on mortality	1 year
YLL per PBC death averted	2
(9) All big four programmes	£16,432
(10) 11 PBCs (with mortality)	£32,387
(11) All 23 PBCs (zero health effects for remaining 12 PBCs)	£119,155
(12) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	£36,604

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

Estimates of the average disease durations across the PBCs used in this calculation are depicted in *Table 123* [see column (2)].[j] These were obtained from the GBD study (see *Addendum 1: data sources*). Although this lower bound for the threshold combines optimistic assumptions, it is possible, indeed likely, that at least some expenditure may have effects on the health outcomes of future patients who are not currently part of the population at risk in a PBC, e.g. investments or disinvestment in prevention will have an impact on populations that are incident to PBCs in the future. Such effects are not captured in any of the estimates presented in this chapter so all are conservative with respect to this type of health effect of changes in expenditure.

The upper bound [see lines (9)–(12) in *Table 122*] is based on the combination of assuming that health effects are restricted to 1 year for the population currently at risk and that any death averted is only averted for the minimum duration consistent with the mortality data. The econometrics work used the average of 3 years of mortality (2006–8), so the estimated outcome elasticities are based on differences in mortality that remain after averaging over 3 years. Therefore, the estimated effects are based on differences in observed PBC deaths that must have been sustained, on average, for more than a minimum of 2 years. This is because variation in mortality in the first year of data will only contribute to estimates if differences are sustained for a minimum of 3 years, variation in mortality in the second year will only contribute if it is

TABLE 123 Disease duration by PBC (GBD)

PBC	(1) Duration of disease for an incident patient (years) (GBD)	(2) Remaining duration of disease for at risk population (years) (GBD)
1	6.21	3.11
2	1.19	0.59
3	1.07	0.53
4	24.83	12.42
5	7.41	3.70
6	3.46	1.73
7	30.91	15.45
8	13.96	6.98
9	16.40	8.20
10	3.21	1.61
11	11.24	5.62
12	0.33	0.17
13	0.27	0.13
14	1.01	0.50
15	9.56	4.78
16	3.74	1.87
17	1.11	0.56
18	0.58	0.29
19	9.71	4.86
20	0.93	0.47
21	1.07	0.53
22	3.74	1.87

sustained for a minimum of 2 years, and in the third year only if sustained for 1 year. If differences in mortality are similar each year (the 3 years contribute equally to the estimates), then estimated effects must have been sustained, on average, for a minimum of 2 years.[k] These estimates can be interpreted as an upper bound given the data available and therefore the analysis that has been feasible.

Adjusting life-years for quality of life

The central or best estimates of the cost per life-year threshold, which were presented in *Table 122* [see lines (2) and (4)], take no account of the health-related QoL in which years of life, expected to be gained or lost through changes in expenditure, are likely to be lived. Even if attention is restricted to the direct health consequences of changes in mortality, estimates of the cost per life-year will tend to overestimate the effects of changes in expenditure (underestimate the threshold) compared with a more complete measure of health that accounts for the quality in which the years of life are expected to be lived. In this section we examine the ways in which the life-years reported in *From mortality to life-years* can be adjusted for quality, taking account of information that is available about (i) how QoL differs by age and gender (see *From mortality to life-years*); and (ii) how the quality of life-years associated with mortality changes might be affected by the types of diseases that make up each PBC (see *Adjusting life-years for quality of life*). Throughout we continue to account for counterfactual deaths in the way described

in *Years of life lost and accounting for counterfactual deaths,* by making the adjustment for quality to the life-years associated with every observed death, before calculating a quality-adjusted net YLL. The implications for a cost per QALY threshold that only accounts for the health effects of mortality changes are presented in *Using estimates of the quality-adjusted life-year burden of disease*. In *Including quality-of-life effects during disease* we explore the ways in which the likely direct effects of expenditure on QoL (other than through mortality) might also be taken into account.

Quality of life based on the general population

The most commonly used metric of health-related QoL in the UK is EQ-5D,[91] which is specified in the NICE reference case for methods of technology appraisal.[153] This metric has five dimensions of quality, each with three possible levels. Each of these 243 possible health states is valued relative to a score of 1, which represents full or best imaginable health (the best score across all five dimensions), and a score of 0, which represents death, based on a representative sample of the UK population.[92] Therefore, insofar as the years of life expected to be gained or lost through changes in expenditure would be lived in this state of full health, the cost per life-year thresholds reported in *Table 122* would also be the cost per QALY thresholds, albeit ones that only account for the health effects of mortality changes.

However, unsurprisingly, there is good evidence that, on average, the general population is not in this state of full health. Therefore, the QoL score associated with the health states experienced by the general population are less than 1, and are expected to decline with age and to differ by gender. These QoL 'norms' for the general population by age and gender are illustrated in *Figure 49* based on an analysis of data from the HSE (see *Addendum 1: data sources* for a description of HSE data and the analysis of QoL norms illustrated in *Figure 49*).

These QoL norms can be applied to the YLL associated with all observed deaths in each PBC, taking account of gender and age at death. The results are reported in columns (4)–(6) of *Table 124*.

There are two effects of adjusting life-years for quality: (i) since QoL norms are always less than 1 the adjusted YLL and YLG are always lower than the unadjusted values in *Table 124*, columns (1) and (2) (previously reported in *Table 106*); and (ii) deaths above LE are necessarily at older ages with poorer QoL norms than those below, so the difference between adjusted and unadjusted values is greater for YLG than YLL (*Table 125* illustrates these effects by showing the implied QoL scores applied to YLL and YLG). The overall effect of quality adjustment on net YLL is the balance of these two effects, and tends to reduce the net YLL [compare columns (3) and (6) in *Table 124*]. The only exception is PBC 11 (respiratory) which has a large proportion of deaths occurring above the LE of the PBC population (see *Table 114*).

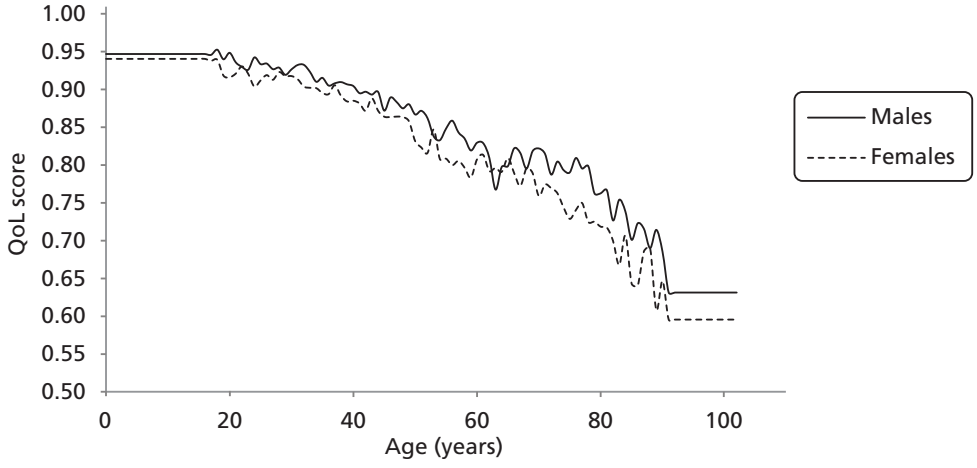


FIGURE 49 Quality of life for the general population by age and gender.

TABLE 124 Net YLL adjusted for QoL 'norms'

PBC		Unadjusted life-years			QALYs		
		(1) YLL	(2) YLG	(3) Net YLL	(4) YLL	(5) YLG	(6) Net YLL
1	Infectious diseases	58,686	21,724	36,962	47,481	14,618	32,864
2	Cancer	1,473,733	126,549	1,347,184	1,143,445	84,036	1,059,409
4	Endocrine	66,283	15,058	51,225	52,856	9973	42,883
7	Neurological	135,686	41,770	93,917	109,349	28,262	81,087
10	Circulatory	1,102,020	278,251	823,768	848,046	183,330	664,717
11	Respiratory	298,343	230,313	68,030	231,578	154,743	76,835
13	Gastrointestinal	273,117	45,414	227,703	216,256	30,277	185,979
17	Genitourinary	47,229	29,101	18,127	35,929	18,947	16,982
18 + 19	Maternity and neonates	16,801	0	16,801	14,568	0	14,568

TABLE 125 Implied QoL score in the net YLL adjustment for QoL 'norms'

PBC		(1) QoL score for YLL	(2) QoL score for YLG
1	Infectious diseases	0.81	0.67
2	Cancer	0.78	0.66
4	Endocrine	0.80	0.66
7	Neurological	0.81	0.68
10	Circulatory	0.77	0.66
11	Respiratory	0.78	0.67
13	Gastrointestinal	0.79	0.67
17	Genitourinary	0.76	0.65
18 + 19	Maternity and neonates	0.87	N/A

N/A, not applicable.

The quality-adjusted net YLL figures in *Table 124*, column (6) suggest that the health effects of mortality are lower than when relying only on unadjusted life-years in *Years of life lost and accounting for counterfactual deaths*. Therefore, the health effects of changes in expenditure on this more complete measure of health will also be lower. The implications of these adjustments to a cost per QALY threshold that only accounts for the direct health effects of mortality are summarised in *Table 126*, and detailed in *Table 127*. As expected, the cost per QALY threshold based on adjusting the YLGs or lost [see *Table 126*, column (2)] is higher than a threshold based on unadjusted life-years [see *Table 126*, column (1), these results were previously reported in *Tables 115* and *122*].

Table 128 depicts the judgements over life-years, QoL weights and total QALYs implicit in calculations of the threshold cost per QALY in *Table 126*. Specifically, columns (1) and (2) of *Table 128* report the number of life-years associated with each death averted for each PBC; as expected, the values are equal to those in *Table 121* as estimates rely on the net YLL evaluated in *Years of life lost and accounting for counterfactual deaths*. In columns (3) and (4), the number of QALYs gained associated with each death averted are presented. These ranged from 64.46 QALYs gained per PBC death averted for PBCs 18 and 19 (maternity and neonates) to 1.17 QALYs per PBC death averted for PBC 11 (respiratory), see column (4).

TABLE 126 Summary of cost per QALY threshold based on population norms and mortality effects

PBC grouping	(1) Cost per life-year threshold (£)	(2) Cost per QALY threshold (population norms) (£)
All big four programmes	8080	9631
11 PBCs (with mortality)	15,628	18,622
All 23 PBCs[a]	17,663	21,047

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal except GMS.

TABLE 127 A breakdown of the cost per QALY threshold based on population norms

PBC		(1) Change in spend (£M)	(2) Change in QALY	(3) Cost per QALY gained (£)
2	Cancer	19	1685	11,378
10	Circulatory problems	33	5147	6464
11	Respiratory problems	22	1368	16,304
13	Gastrointestinal problems	17	1274	12,952
All big four programmes				*9631*
1	Infectious diseases	8	12	682,211
4	Endocrine problems	18	344	51,309
7	Neurological problems	17	56	307,201
17	Genitourinary problems	32	8	4,020,316
16	Trauma and injuries	10	0	N/A
18 + 19	Maternity and neonates	8	16	509,044
First 11 PBCs				*18,622*
3	Disorders of blood	11	601	18,622
5	Mental health disorders	204	10,964	18,622
6	Learning disability	31	1653	18,622
8	Problems of vision	24	1298	18,622
9	Problems of hearing	6	343	18,622
12	Dental problems	23	1262	18,622
14	Skin	11	565	18,622
15	Musculoskeletal system	15	812	18,622
20	Poisoning and adverse effects	4	236	18,622
21	Healthy individuals	18	985	18,622
22	Social care needs	68	3630	18,622
23	Other	78	0	N/A
All 23 PBCs				*21,047*

N/A, not applicable.

TABLE 128 Implied YLL per excess death averted and implied QoL score per YLL gained, for each PBC

PBC		(1) Implied YLL per excess death averted	(2) Implied YLL per PBC death averted	(3) Implied QALYs gained per excess death averted	(4) Implied QALYs gained per PBC death averted
2	Cancer	14.07	10.30	11.07	8.10
10	Circulatory	10.40	5.15	8.39	4.16
11	Respiratory	9.21	1.04	10.40	1.17
13	Gastrointestinal	14.98	9.43	12.24	7.70
All big four programmes		*11.28*	*4.07*	*9.46*	*3.41*
1	Infectious diseases	13.21	5.31	11.75	4.72
4	Endocrine	13.59	7.57	11.38	6.34
7	Neurological	13.59	6.12	11.74	5.28
17	Genitourinary	8.34	1.71	7.82	1.60
16	Trauma and injuries	N/A	N/A	N/A	N/A
18 + 19	Maternity and neonates	74.34	74.34	64.46	64.46
First 11 PBCs		*11.37*	*4.14*	*9.54*	*3.48*

N/A, not applicable.

In general, these values are expected to be smaller than the unadjusted YLL per PBC death averted in column (2). The exception is PBC 11 (respiratory) – in this PBC, the number of YLL and YLG are more similar than in other PBCs [respectively, columns (1) and (2) of *Table 124*], and given that YLG are weighted more heavily (with lower QoL scores) than YLL, the netting of adjusted estimates returns a higher number than the netting of unadjusted estimates. On average, across all 11 PBCs each PBC death averted is associated with 3.5 QALYs gained.

Adjusting age-related quality-of-life for disease decrements

Adjusting life-years for age- and gender-related QoL norms assumes that any YLG through a change in expenditure would be lived in a similar QoL to the general population. It is possible, however, that patients benefiting from reduced mortality may, nevertheless, continue to be affected by the type of diseases that make up each PBC and experience the QoL associated with the original disease.

The HODaR[93] provides over 30,000 observations of EQ-5D measures of QoL by ICD-10 code and the age and gender of the patients in the sample (see *Addendum 1: data sources*). Although this is a rich UK data set, there were a limited number of observations for some of the less common ICD-10 codes. For this reason HODaR was supplemented with information from the MEPS[94] which also provides EQ-5D by ICD and reports the average age of respondents (see *Addendum 1: data sources*). These data provided a means of estimating the QoL associated with each ICD-10 code at the average age of respondents in the pooled sample (ICD-10 code estimates of the QoL score and age were pooled across data sets by considering the number of patients from each data set contributing to estimates, i.e. a weighted average). The QoL associated with each PBC was then expressed as the average of the QoL associated with its component ICD-10 codes. The average QoL scores across ICD-10 codes which contribute to each PBC and the average age and gender of respondents were used to calculate a PBC disease-related decrement (disutility) based on QoL norms from the general population – it is important to note that by expressing the QoL effects of different diseases as age-related decrements we do not require the HODaR and MEPS samples to necessarily be representative of the age distribution of the population at risk in the PBCs.

Table 129 summarises the data from HODaR and MEPS and the QoL decrements used in further calculations of the threshold, namely the number of patients for which QoL scores were available [see column (1)]; the average age of these patients by gender [see columns (2) and (3)]; the average QoL scores across PBCs [see column (4)]; the QoL scores for the population norms by gender [see columns (5) and (6)]; and the calculated disease-related decrements [see columns (7) and (8)].

Figure 50 illustrates the use of the decrement to QoL norms for PBC 1 (infectious disease) across a range of ages. For PBC 1, the QoL score, evaluated across the component ICD-10 codes, was found to be 0.667 in HODaR and MEPS, at an average age of 54 years for male respondents. As the QoL norms for males aged 54 years is 0.859, this suggests a decrement associated with membership of PBC 1 of 0.192, which can then be applied to QoL norms by age as illustrated in *Figure 50*.

TABLE 129 Quality-of-life scores per PBC from different sources

	HODaR/MEPS				Population norms		Disease-related decrement compared with population norms	
		Average age		(4) QoL score for diseased				
PBC	(1) *n*	(2) Male	(3) Female		(5) Male	(6) Female	(7) Male	(8) Female
1	263	54.0	47.1	0.667	0.859	0.830	0.192	0.163
2	13,324	64.3	59.8	0.692	0.809	0.830	0.117	0.138
3	2464	58.6	58.1	0.656	0.859	0.830	0.203	0.174
4	7128	57.3	56.5	0.701	0.859	0.830	0.157	0.128
5	12,733	47.8	47.9	0.557	0.859	0.830	0.301	0.272
6	301	25.8	25.3	0.671	0.937	0.924	0.266	0.253
7	10,296	55.8	53.8	0.546	0.859	0.830	0.312	0.283
8	11,536	63.8	64.5	0.719	0.809	0.796	0.089	0.077
9	1023	61.7	59.8	0.778	0.809	0.830	0.031	0.051
10	33,854	64.4	64.1	0.629	0.809	0.796	0.179	0.167
11	19,646	48.4	47.2	0.634	0.859	0.830	0.224	0.195
12	1811	40.9	40.0	0.781	0.910	0.894	0.129	0.113
13	23,138	57.3	55.5	0.653	0.859	0.830	0.206	0.177
14	5659	54.8	54.0	0.695	0.859	0.830	0.164	0.134
15	34,590	56.4	56.6	0.578	0.859	0.830	0.280	0.251
16	2652	46.0	58.3	0.652	0.859	0.830	0.207	0.178
17	13,651	57.5	53.0	0.711	0.859	0.830	0.147	0.118
18 + 19	1566	37.8	31.7	0.848	0.910	0.894	0.063	0.047
20	1569	59.1	52.3	0.584	0.859	0.830	0.275	0.246
21	7488	60.6	60.3	0.661	0.809	0.796	0.147	0.135
22	25	78.4	81.4	0.156	0.798	0.636	0.642	0.480
23	1002	62.6	60.8	0.639	0.809	0.796	0.170	0.158

No gender details were available from MEPS so assumed 50 : 50 split of frequency.
Only primary diagnosis is used from HODaR data.
A lower bound of 0 is assumed for disutility for each PBC.

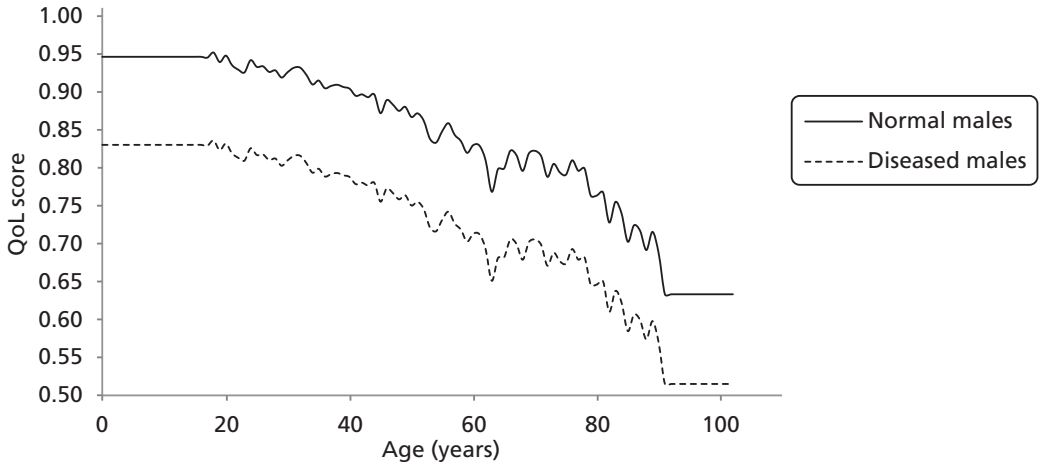


FIGURE 50 Quality of life for males in PBC 1 (infectious disease) and the general population by age.

In principle, it would be possible to estimate disease-related disutility by age rather than assume a fixed additive decrement. HODaR does provide age for each reported QoL score, but MEPS only provides average age of respondents in published summaries. However, even with access to 'raw' scores and the age and gender of each, it is very unlikely that there would be sufficient data to estimate age-related decrements in each of the component ICD-10 codes. It would, however, be possible to assume a proportionate rather than fixed decrement by age. However, the average age of respondents in the pooled HODaR and MEPS sample [see columns (2) and (3) of *Table 129*] tends to be older than the age distribution of the PBC populations [see columns (3) and (4) of *Table 113*]. Given that older individuals are expected to have a lower QoL (norm), relative decrements can overestimate the decrements observed in younger patients. By applying overestimated decrements, the quality-adjusted net YLL would be underestimated and the cost per QALY threshold increased compared with the fixed decrement applied here.

Quality-of-life norms adjusted for disease-related decrements can be applied to the YLL associated with observed deaths in each PBC, taking account of gender and age at death in the same way as *From mortality to life-years*. To do so, the 'PBC decrements' calculated from HODaR and MEPS were applied to each observed death and the age at which each life-year was gained or lost (from ONS). The results are reported in columns (4)–(6) of *Table 130*. The overall effect of quality adjustment that also applies a disease-related decrement is to reduce the net YLL to a greater extent than adjustment with population norms alone [compare column (6) in *Table 130* with column (6) in *Table 124*].

TABLE 130 Net YLL adjusted for disease- and age-related QoL

		Unadjusted life-years			QALYs		
PBC		(1) YLL	(2) YLG	(3) Net YLL	(4) YLG	(5) YLL	(6) Net YLG
1	Infectious diseases	58,686	21,724	36,962	37,055	10,793	26,262
2	Cancer	1,473,733	126,549	1,347,184	955,690	67,930	887,760
4	Endocrine	66,283	15,058	51,225	43,394	7844	35,550
7	Neurological	135,686	41,770	93,917	68,893	15,842	53,050
10	Circulatory	1,102,020	278,251	823,768	656,145	135,241	520,905
11	Respiratory	298,343	230,313	68,030	169,269	106,505	62,764
13	Gastrointestinal	273,117	45,414	227,703	163,593	21,677	141,916
17	Genitourinary	47,229	29,101	18,127	29,749	15,152	14,598
18 + 19	Maternity and neonates	16,801	0	16,801	13,662	0	13,662

The implied QoL weights (considering the disease-related decrements) for YLL and YLG are shown in *Table 131*. Note that, as expected, the weights assume a lower value than in *Table 125*.

Combining QoL adjustments for both population norms and disease-related decrements assumes that any YLGs due to a reduction in mortality will be lived in the diseased state until LE (i.e. that all diseases are not just chronic but disease duration is lifelong). Inevitably, this assumption means that the health effects of changes in mortality will be reduced. Consequently, the cost per QALY threshold reported in *Table 132* [see column (2)] will be higher than adjusting YLGs for population norms in *Table 126* [see column (2)]. A detailed breakdown of the cost per QALY threshold based on disease-related disability and mortality effects is shown is *Table 133*.

The number of YLGs associated with each death averted [columns (1) and (2) in *Table 134*] is, again, consistent with previous estimates (see *Tables 121* and *128*). The average number of QALYs gained across all 11 PBCs is 2.8 QALYs per death averted [see column (4) in *Table 134*]. As expected this value is lower than in the previous section [see column (4) in *Table 128*].

TABLE 131 Implied QoL weights in the net YLL adjusted for disease- and age-related QoL

PBC		(1) QoL weights for YLL	(2) QoL weights for YLG
1	Infectious diseases	0.63	0.50
2	Cancer	0.65	0.54
4	Endocrine	0.65	0.52
7	Neurological	0.51	0.38
10	Circulatory	0.60	0.49
11	Respiratory	0.57	0.46
13	Gastrointestinal	0.60	0.48
17	Genitourinary	0.63	0.52
18 + 19	Maternity and neonates	0.81	N/A

N/A, not applicable.

TABLE 132 Summary of cost per QALY threshold based on disease-related disutility

PBC scenario	(1) Cost per life-year threshold (£)	(2) Cost per QALY threshold (£) disease-related disutility
All big four programmes	8080	12,109
11 PBCs (with mortality)	15,628	23,395
All 23 PBCs (zero health effects for remaining 12 PBCs)	57,497	86,072
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	17,663	26,441

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal except GMS.

TABLE 133 Breakdown of the cost per QALY threshold based on disease-related disutility

PBC		(1) Change in spend (£M)	(2) Change in QALY	(3) Cost per QALY gained (£)
2	Cancer	19	1412	13,578
10	Circulatory problems	33	4034	8248
11	Respiratory problems	22	1117	19,960
13	Gastrointestinal problems	17	972	16,974
All big four programmes			*0*	*12,109*
1	Infectious diseases	8	10	853,712
4	Endocrine problems	18	285	61,892
7	Neurological problems	17	37	469,558
17	Genitourinary problems	32	7	4,676,874
16	Trauma and injuries	10	0	N/A
18 + 19	Maternity and neonates	8	15	542,801
First 11 PBCs			*0*	*23,395*
3	Disorders of blood	11	479	23,395
5	Mental health disorders	204	8727	23,395
6	Learning disability	31	1316	23,395
8	Problems of vision	24	1033	23,395
9	Problems of hearing	6	273	23,395
12	Dental problems	23	1004	23,395
14	Skin	11	449	23,395
15	Musculoskeletal system	15	647	23,395
20	Poisoning and adverse effects	4	188	23,395
21	Healthy individuals	18	784	23,395
22	Social care needs	68	2890	23,395
23	Other	78	0	N/A
All 23 PBCs				*26,441*

N/A, not applicable.

TABLE 134 Implied YLL per death averted and implied QoL score per YLL gained, for each PBC

PBC		(1) Implied YLL per excess death averted	(2) Implied YLL per PBC death averted	(3) Implied QALYs gained per excess death averted	(4) Implied QALYs gained per PBC death averted
2	Cancer	14.07	10.30	9.28	6.79
10	Circulatory	10.40	5.15	6.58	3.26
11	Respiratory	9.21	1.04	8.50	0.96
13	Gastrointestinal	14.98	9.43	9.34	5.88
All big four programmes		*11.28*	*4.07*	*7.53*	*2.71*
1	Infectious diseases	13.21	5.31	9.39	3.77
4	Endocrine	13.59	7.57	9.43	5.26
7	Neurological	13.59	6.12	7.68	3.46
17	Genitourinary	8.34	1.71	6.72	1.37
16	Trauma and injuries	N/A	N/A	N/A	N/A
18 + 19	Maternity and neonates	74.34	74.34	60.45	60.45
First 11 PBCs		*11.37*	*4.14*	*7.60*	*2.77*

N/A, not applicable.

Summary of the cost per quality-adjusted life-year threshold based only on mortality effects

The analysis to this point is summarised in *Table 135*. The three estimates of a cost per QALY threshold are based on assuming that each YLG is either lived in full health [see column (1), equal to the cost per life-year estimates in *Table 122*]; lived in a QoL that reflects age and gender norms of the general population [see column (2)]; or lived in a QoL that reflects the original disease state [see column (3)].

The weights reflecting the quality in which the years of life saved are lived in each of these three estimates is shown in *Table 136*.

Assuming that YLGs are lived in full health is not credible and should be regarded as an underestimate of the threshold given what is known about QoL norms for the general population (see *Figure 49*). Equally, assuming that all YLGs are lived in the QoL of the original disease state does not seem credible either, and is likely to overestimate the threshold as it assumes that all disease is not only chronic but lifelong and all life-years would be lived in the diseased state until death. The information that is available about disease duration suggests that many types of disease that comprise the PBCs are not chronic and certainty not lifelong (see *Table 123*). Although adjusting YLGs for the QoL of the general population, taking account of age and gender [see column 2 in *Table 135*), is likely to underestimate the cost per QALY threshold based only on mortality effects, it probably represents the 'best' of the three alternative estimates available at this stage of the analysis. The lower and upper bounds are based on combining optimistic and pessimistic assumptions about the duration of health effects and how long a death might be averted as described in *Summary of cost per life-year estimates*.

However, it should be noted that these cost per QALY thresholds only account for the direct health effects of changes in mortality due to changes in expenditure. Insofar as much, or at least some part, of NHS activity and expenditure is intended to improve QoL, not just mortality, then these estimates will underestimate total health effects and overestimate a cost per QALY threshold based on a more complete

TABLE 135 Summary of QALY threshold estimates based only on mortality effects

PBC grouping	(1) QoL score = 1	(2) QoL norm	(3) QoL diseased
Best estimate			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	~4.1 YLL[a]	~4.1 YLL[a]	~4.1 YLL[a]
QALYs per death averted	~4.1 QALYs	~3.5 QALYs	~2.8 QALYs
(1) All big four programmes	£8080	£9631	£12,109
(2) 11 PBCs (with mortality)	£15,628	£18,622	£23,395
(3) All 23 PBCs[a]	£17,663	£21,047	£26,441
Lower bound			
Effect of expenditure on mortality	Remainder of disease	Remainder of disease	Remainder of disease
YLL per PBC death averted	~4.1 YLL	~4.1 YLL	~4.1 YLL
QALYs per death averted	~4.1 QALYs	~3.5 QALYs	~2.8 QALYs
(4) All big four programmes	£3846	£4252	£5319
(5) 11 PBCs (with mortality)	£6106	£6852	£8568
(6) All 23 PBCs[a]	£6901	£7744	£9683
Upper bound			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per PBC death averted	2 YLL	2 YLL	2 YLL
QALYs per death averted	2 QALYs	~1.9 QALYs	~1.5 QALYs
(7) All big four programmes	£16,432	£17,456	£21,747
(8) 11 PBCs (with mortality)	£32,387	£34,492	£42,967
(9) All 23 PBCs[a]	£36,604	£38,983	£48,561

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal except GMS.

TABLE 136 Implied QoL weight per YLL gained

PBC		(1) Full health	(2) Population norms	(3) Disease-related disutility
2	Cancer	1	0.79	0.66
10	Circulatory	1	0.81	0.63
11	Respiratory	1	1.13	0.92
13	Gastrointestinal	1	0.82	0.62
All big four programmes		*1*	*0.84*	*0.67*
1	Infectious diseases	1	0.89	0.71
4	Endocrine	1	0.84	0.69
7	Neurological	1	0.86	0.56
17	Genitourinary	1	0.94	0.81
16	Trauma and injuries	N/A	N/A	N/A
18 + 19	Maternity and neonates	1	0.87	0.81
First 11 PBC's		*1*	*0.84*	*0.67*

N/A, not applicable.

measure of possible health effects. In *Including quality-of-life effects during disease* we explore the ways in which the likely effects of expenditure on QoL (other than through mortality) might also be taken into account.

Including quality-of-life effects during disease

The cost per QALY thresholds presented in *Adjusting life-years for quality-of-life* only account for the health (QALY) effects of changes in mortality due to changes in expenditure. It does not seem credible to suppose that all NHS activity and expenditure only influences mortality with no effect on the QoL while alive and experiencing a disease. Insofar as changes in NHS expenditure will also affect QoL, as well as mortality, then total health effects will be underestimated and the thresholds presented in *Table 135* will overestimate the cost per QALY threshold. In this section we explore ways to also take account of those effects on health not directly associated with mortality and life-year effects (i.e. the 'pure' QoL effects) to estimate an overall cost per QALY threshold.

The routine reporting of QoL outcomes are increasingly available at PCT level (see *Addendum 1: data sources* for a description of these data). In principle, the variation in such measures of outcome across PCTs could be used to estimate outcome elasticities for QoL rather than mortality effects using similar econometric methods to those described in *Appendix 2* (see *Application of method to other non-mortality-based outcome indicators* for the results of an exploratory econometric analysis of these data). However, the currently limited coverage of routine reporting of these outcomes means that it is not feasible to estimate QoL effects across all the PBCs using these data. Here we explore how estimates of effects of expenditure that can be observed (i.e. on mortality) can be used to infer the likely effects on what cannot be directly observed (QoL), rather than making extreme assumptions that are not credible (e.g. assuming that changes in expenditure will have no effects on QoL outcomes).

In *Using ratios of quality-adjusted life-years to years of life lost* we use three alternative estimates of the ratio of QALYs to life-years lost due to different types of disease as a means of inferring the change in QALYs that is likely to be associated with the estimated change in YLL (i.e. applying the total QALYs lost associated with each YLL with disease). This is consistent with regarding the estimates of the mortality and life-year effects as a surrogate for a more complete measure of the health effects of a change in expenditure.

However, these ratios of QALYs lost to life-years lost due to disease in those PBCs where outcome elasticities could not be estimated cannot inform estimates of the threshold (there are no estimated life-year effects with which to apply the ratios). Nonetheless, the sources of information on which ratios are based also provide much of the information required to calculate the QALY burden of disease in these areas, which can be used to inform estimates of the threshold. Therefore, in *Using estimates of the quality-adjusted life-year burden of disease* we use an estimate of the QALY burden of disease, infer a proportionate effect on burden from the observed effects on life-years, and then apply this proportionate effect to the measures of QALY burden for all the other PBCs. In this way we can use all the information available about the mortality and QoL effects of the different types of disease that make up each PBC, including those where mortality-based outcome elasticities are not available.

Using ratios of quality-adjusted life-years to years of life lost

The ratio of the total QALYs to YLL due to a disease indicates the number of QALYs associated with each year of life lost. Therefore, any change in YLL is expected to generate a number of QALYs indicated by the ratio – in this way, the estimated effects on mortality and life-years are interpreted as a surrogate for a more complete measure of total health effects, which is reasonable. For example, a disease with a ratio > 1 suggests that each year of life lost across the at risk population is associated with more than one QALY (i.e. there are significantly greater QoL effects while experiencing the disease). Therefore, a change in expenditure that leads to 1 YLG in this type of disease may generate a greater QALY effect than the same life-year effects in a disease where this ratio is < 1 (i.e. where most of the effect of disease is on mortality rather than QoL). Therefore, using these ratios provides a means of accounting for the likely effect on QoL other than through effects on mortality.

To understand the differences between the three ratios presented below, it is useful to regard the total QALYs lost to YLL ratio (R) for a particular disease as the sum of two ratios: (i) the QALYs lost due to premature death to YLL ratio (R_{death}); and (ii) the QALYs lost during disease (while alive) to YLL ratio (R_{alive}), as depicted in *Equation 25*.

$$R = \frac{QALYs\ lost}{YLL} = \underbrace{\frac{QALYs\ lost_{premature\ death}}{YLL}}_{R_{death}} + \underbrace{\frac{QALYs\ lost_{while\ alive}}{YLL}}_{R_{alive}} \tag{25}$$

Insofar as YLL would not have been lived in full health, the QoL effects captured in R_{death} are estimated to be lower than 1. Note that the analyses in *Adjusting life-years for quality-of-life* already imply a R_{death} ratio at PBC level. The second component of the ratio, R_{alive}, represents QALYs lost during disease for the at risk population as a proportion of the YLL observed in the same population – in diseases for which QoL during disease is compromised but LE is not changed significantly R_{alive} may thus assume high values. The ratios do not represent the balance of QALY gains due to mortality and morbidity in a single patient, but rather in the population. Where R_{death} is < 1, only when the pure QALY effects offset the less than full QoL of the YLL is the ratio > 1. Therefore, ratios < 1 are possible even when disease has measurable QoL effects for those experiencing it.

Disability-adjusted life-year to years of life lost ratios

The WHO GBD study provides UK-specific estimates of the YLD and the YLL due to different types of disease. Diseases in GBD are classified using U-codes that can then be mapped to ICD-10 codes, as illustrated in *Table 137* (*Addendum 1: data sources* provides more details on the mapping procedure). GBD uses DALYs as a measure of the burden of disease. This DALY measure has two components: (i) the YLD, which evaluates the number of years lived with disability over the durations of disease, and incorporates weights (between zero and one) to reflect the scale of disability experienced in each year; and (ii) the YLL.

The total DALYs associated with a disease is simply YLL + YLD. Therefore, the DALYs to YLL ratio is (YLL + YLD)/YLL or equivalently YLL/YLL + YLD/YLL. As the first term (YLL/YLL = R_{death}) must equal 1 and the second (R_{alive} = YLD/YLL) must be ≥ 0, a ratio based on DALYs must necessarily be bounded by one.

$$R_{DALY} = \frac{DALYs}{YLL} = \frac{(YLL + YLD)}{YLL} = \underbrace{1}_{R_{death}} + \underbrace{\frac{YLD}{YLL}}_{R_{alive}} \tag{26}$$

This is illustrated in *Table 138* for the four different diseases (classified by U-codes) introduced in *Table 137* which reflect diseases where mortality is the major component (e.g. U016) and where the impact of disease on the QoL while alive is the major component (e.g. U141).

TABLE 137 Illustration of the mapping between U-code and ICD-10 code

U-code	ICD-10 codes
U037 (other infectious diseases)	A02, A05, A20–A28, A31, A32, A38, A40–A49, A65–A70, A74–A79, A81, A82, A83.1–A83.9, A84–A89, A92–A99, B00–B04, B06–B15, B25–B49, B58–B60, B64, B66–B72, B74.3–B74.9, B75, B82–B89, B92–B99, G04
U016 (tetanus)	A33–A35
U061 (mouth and oropharynx cancers)	C00–C14
U057 (iron-deficiency anaemia)	D50, D64.9

TABLE 138 Examples of DALY to YLL ratios

U-code	DALY ratios	$(R_{death} + R_{alive})$
U037 (other infectious diseases)	1.23	(1 + 0.23)
U016 (tetanus)	1.00	(1 + 0)[a]
U061 (mouth and oropharynx cancers)	1.05	(1 + 0.05)
U141 (spina bifida)	2.34	(1 + 1.34)[b]

a Given the short disease duration, it is only mortality effects that contribute to the ratio.
b QoL effects during disease contribute significantly to estimates of the ratio.

Note that the estimates of GBD YLL used here are derived using UK data on mortality (relating to the year 2004) by age and gender groups – we assume these data to be from ONS and, thus, consistent with the data used in this work. However, the calculation of YLL in GBD differs from both the approach adopted by the NHS IC and the approach adopted here of using net YLL. For each death observed in the data, GBD evaluates YLL by considering the LE at the age at which the death occurred (and gender).[154] This is expected to overestimate net YLL (which accounts for counterfactual deaths, as detailed in *Summary of the cost per quality-adjusted life-year threshold based only on mortality effects*). This will make no difference to the first term in the QALY ratio (R_{death}) as an overestimate of YLL affects both denominator and numerator of the ratio. However, the second term (R_{alive}) is likely to be underestimated. Therefore, the ratios will tend to underestimate the QALY effects of expenditure and overestimate the cost per QALY threshold. This will be adjusted for in *Using estimates of the quality-adjusted life-year burden of disease*, where our preferred analysis based on burden of disease is presented.

Adjusting disability-adjusted life-years for quality-of-life norms

The use of DALY ratios bounded below by 1 essentially assumes that YLL would have otherwise been lived in a state of full health. As was discussed in *Using ratios of quality-adjusted life-years to years of life lost*, this is not credible given information available about the QoL in the general population (see *Figure 49*). It would lead to overestimating the QALYs associated with mortality and life-year effects and underestimating the cost per QALY threshold. Therefore, it is important to adjust these DALY ratios for the QoL norms by age and gender in the same way as described in *Using ratios of quality-adjusted life-years to years of life lost*. *Equation 27* shows how the adjusted ratio is formulated when YLL are adjusted by the QoL in the general population, u_n. This is a simplified representation of the adjustment as despite gender and age having been considered in calculations these are not shown in the notation below.

$$R_{DALY\ adj} = \frac{u_n \times YLL}{YLL} + \frac{YLD}{YLL} = \underbrace{u_n}_{R_{death}} + \underbrace{\frac{YLD}{YLL}}_{R_{alive}} \tag{27}$$

The effect of this adjustment (within each U-code, see *Addendum 1: data sources*) is illustrated in *Table 139*. Now those types of disease where mortality rather than QoL with the disease is the major component can have ratios < 1. Indeed, the first term of these ratios (R_{death}) is consistent with (but not equivalent to) the analysis in *Using ratios of quality-adjusted life-years to years of life lost*, where the ratio of quality adjusted net YLL to unadjusted net YLL represents this ratio on average for each PBC.

TABLE 139 Examples of adjusted DALY to YLL ratios

U-code	Adjusted DALY ratios	($R_{death} + R_{alive}$)
U037 (other infectious diseases)	1.01	(0.78 + 0.23)
U016 (tetanus)	0.78	(0.78 + 0)
U061 (mouth and oropharynx cancers)	0.83	(0.78 + 0.05)
U141 (spina bifida)	2.18	(0.85 + 1.34)

Using quality-of-life estimates (based on the Health Outcomes Data Repository and Medical Expenditure Panel Survey)

The disability weights used in the DALY measure (in R_{alive}) are not based on the same description of health states as the EQ-5D measure, nor are the weights based on a representative sample of the UK population responding to choice-based elicitation questions. EQ-5D based QoL decrements (in relation to age adjusted QoL norms) associated with different types of disease can be estimated from HODaR and MEPS data for the groups of ICD-10 codes that make up each U-code. The calculations of the QoL decrements from HODaR were conducted as previously described in *Adjusting age-related quality-of-life for disease decrements*. In summary, the average QoL scores across the ICD-10 codes which contribute to each U-code (based on the contributing ICD-10 codes, see *Table 137* and *Addendum 1: data sources* for how ICD-10 codes map to U-codes) and the average age and gender of respondents from HODaR and MEPS were used to calculate a disease decrement for each U-code, based on QoL norms from the general population. Note that, by expressing the QoL effects of different diseases as age-related decrements (see *Figure 50*), we do not require the HODaR and MEPS samples to necessarily be representative of the age distribution of the population at risk.

The disease-related QoL decrements can then be used to replace the DALY disability weights in R_{alive} reported in *Tables 138* and *139*. This final adjustment is illustrated in *Table 140*; for example, the evidence about QoL from HODaR and MEPS suggests that the impact of U037 on QoL is greater than indicated by DALY disability weights. The QoL effects of U141, although still very significant, are lower than indicated by DALY disability weights.

By turning what were originally DALY ratios into EQ-5D QALY ratios, we regard the QALY to YLL ratios rather than DALY or modified DALY ratios as the preferred basis of estimating a cost per QALY threshold. We consider these estimates to provide a more complete picture of the likely health effects of changes in expenditure.

U-code quality-adjusted life-year ratios to *International Classification of Disease* quality-adjusted life-year ratios

Information about the size and age and gender distribution is only available at U-code level. Therefore U-code ratios are applied to all the ICD-10 codes that contribute to a particular U-code. Note that, unlike ICD-10 codes, U-codes do not map directly to PBCs so some ICD-10 codes in different PBCs may belong to the same U-code and therefore have the same U-code ratio. Some ICD-10 codes are not included in the

TABLE 140 Examples of QALY to YLL ratios (HODaR and MEPS)

U-code	QALY ratios (HODaR and MEPS)	($R_{death} + R_{alive}$)
U037 (other infectious diseases)	1.37	(0.78 + 0.60)
U016 (tetanus)	0.78	(0.78 + 0)
U061 (mouth and oropharynx cancers)	0.80	(0.78 + 0.02)
U141 (spina bifida)	1.88	(0.85 + 1.03)

U-code classification of disease. Some of these are procedural codes (84 out of 1562) where mortality and QALY effects were not assigned mortality or QALY effects anyway (any health effects would be evident in other ICD-10 codes) so it was not necessary to impute ratios for them. Of the others, some were associated with PBC 16 (186 out of 1562) with a zero outcome elasticity so did not require imputation either. Imputation based on the median ratio across the ICD-10 codes within the PBC was required for the remaining (482 out of 1562). Eighty eight of these are not mapped into U-codes – these include three big categories of ICD-10 codes: symptoms and signs (R00–R69); abnormal clinical and laboratory findings, not elsewhere classified (R70–R99); and ill-defined and unknown causes of mortality (R95–R99). The remaining 394 were associated with U-codes where the ratio was undefined because the denominator (YLL) was zero. In both these cases, values were also imputed based on the median ratio across the ICD-10 codes within the PBC. As the distribution of ratios within a PBC tend to be highly positively skewed, imputation based on the median is likely to be conservative with respect to health effects and especially in the latter case where mortality effects appear to be a much less important aspect of the disease.

Table 141 illustrates the variation observed in the ratios (imputed) across ICD-10 codes within the same PBC.

TABLE 141 Percentiles of the ratio across ICD-10 codes, by PBC

PBC		Percentiles of the adjusted DALY ratios						
		5%	15%	25%	50%	75%	85%	95%
2	Cancer	0.76	0.76	0.76	0.81	0.85	0.85	0.91
10	Circulatory problems	0.86	0.86	0.86	0.86	0.96	1.00	2.65
11	Respiratory problems	0.22	0.73	1.00	1.67	1.67	1.96	2.67
13	Gastrointestinal problems	0.86	0.96	1.01	1.63	1.63	1.78	2.73
1	Infectious diseases	0.00	0.83	1.01	1.01	1.01	1.01	2.64
4	Endocrine problems	0.77	1.37	1.43	2.97	2.97	2.97	2.97
7	Neurological problems	0.86	1.01	1.01	2.01	2.01	2.01	2.30
17	Genitourinary problems	0.74	0.77	0.77	1.10	1.10	1.10	12.41
18	Maternity	0.00	0.79	0.81	20.39	20.39	20.39	20.39
19	Neonates	1.17	1.17	1.17	1.17	2.29	2.29	2.29
		Percentiles of the QALY ratios (HODaR and MEPS)						
		5%	15%	25%	50%	75%	85%	95%
2	Cancer	0.76	0.76	0.76	0.79	0.80	0.80	0.83
10	Circulatory problems	0.83	0.83	0.83	0.83	0.94	1.01	1.83
11	Respiratory problems	0.73	0.86	1.37	2.09	2.09	2.24	2.80
13	Gastrointestinal problems	0.84	1.01	1.37	1.70	1.70	2.17	7.10
1	Infectious diseases	0.83	1.37	1.37	1.37	1.37	1.37	3.26
4	Endocrine problems	0.77	2.37	2.55	5.12	5.12	5.12	10.15
7	Neurological problems	0.84	0.90	1.37	5.90	5.90	5.90	5.90
17	Genitourinary problems	0.74	0.78	0.78	0.99	0.99	0.99	9.80
18	Maternity	0.81	0.81	0.83	49.30	49.30	49.30	49.30
19	Neonates	0.87	0.87	0.87	0.88	0.88	0.88	0.88

Allocating effects at programme budget category level to *International Classification of Disease* codes

Tables 138–140 illustrate how QALY ratios can be calculated for and differ by U-code. Unsurprisingly, these ratios differ across the type of diseases that make up each PBC (see *Table 141*). When using this information to estimate a cost per QALY threshold the mortality and life-year effects observed at PBC level must be allocated in some way to the component ICD-10 codes before ratios are applied to life-year effects and the resulting QALY effects are summed across all the contributing ICD-10 codes.

Alternatively, one could calculate an average of the ratios within a PBC and then apply this 'average ratio' to life-year effects at PBC level, rather than calculate QALY effects at ICD-code level by applying the relevant ratio. This would be inappropriate for two reasons. First, ratios should not be averaged; instead, the total QALYs lost and YLL should be summed across ICD-10 codes and the ratio of these sums used to represent a PBC level estimate (i.e. a ratio of averages). Second, even if the appropriate estimate of the QALY to YLL ratio is calculated at the PBC level, this estimate would assume ICD-10 codes to be equally representative of the PBC – i.e. that expenditure would be equally likely to affect any of the ICD-10 codes that compose a particular PBC. This is unlikely to be true not only due to the inherent differences in the disease described by the ICD-10 coding, but also as ICD-10 codes are likely to differ significantly in what concerns the size of the at risk population they represent.

It is important to consider explicitly how other information might inform the different ways in which the effects observed at PBC level might be generated by the distribution of impacts at ICD-10 code level, i.e. where investment or disinvestment is likely to occur within the PBC and therefore which ICD-10 codes are likely to contribute most to overall health effects. An important and complementary element to the econometric analysis of routinely reported information at PBC level, was to investigate this by looking at local level information available within the NHS. The details of this investigation are reported in *Addendum 2: the role of data on local NHS decisions*. The review of local data sources suggested that there is very little routinely collected data on investment and disinvestment by local NHS organisations beyond the high-level aggregate data on spending by PBCs which are used in the econometric analysis. Although more disaggregated data on spending decisions about specific services relevant to particular ICD-10 codes could in principle be acquired through additional primary research (surveys or freedom of information requests) this would be costly and with a risk that information acquired in this way may not be complete, consistent or representative.

In the absence of useful information at a local level, it is possible to assume that a change in PBC expenditure will be allocated equally (on a per patient basis) across the component ICD-10 codes, i.e. any investment or disinvestment is equally likely across the population at risk within the PBC. HES (see *Addendum 1: data sources*) provides information about the costs associated with each ICD-10 code by PCT. The variation in per patient costs between PCTs (where total costs allocated to individual ICD-10 codes were divided by the number of patients using services in the PCT) was analysed to establish which ICD-10 codes contribute most to the variability in HES costs within a PBC, across PCTs. The ICD-10 codes that contribute most to this variance might be expected to be more likely to have been subject to differential investment or disinvestment across PCTs. Unfortunately, total PBC costs are not available at ICD-10 code level across PCTs so could not be used for this purpose. Costs from HES data are only a component of total PBC costs (41% of total PBC costs for the 11 PBCs where mortality effects can be estimated) and contribute less to the variability in PBC costs across PCTs (HES contribute only 23% of the variability for the 11 PBCs where mortality effects can be estimated).

There are differences in relative weight assigned to ICD-10 codes based solely on the size of the population or its contribution to variance in HES costs. If investment or disinvestment within a PBC tends to focus on ICD-10 codes representing areas of marginal value the health effects of a change in PBC expenditure may be overestimated and a cost per QALY threshold underestimated when allocating effects equally across the population at risk within each PBC. However, weighting ICD-10 codes based on HES data is likely to favour those ICD-10 codes which represent more severe disease requiring more hospital care. This may over

represent ICD-10 codes with lower QALY to YLL ratios if mortality effects tend to be a major component of these types of disease and may be conservative with respect to the health effects of changes in expenditure.

The implications for a cost per QALY threshold that uses the estimated mortality and life-year effects as a surrogate for a more complete measure of the likely heath effects (i.e. that includes QoL as well as quality adjusted life-year effects) is summarised in *Table 142*, and detailed in *Table 143*. These results use the contribution to variance in HES costs to 'weight' the different ICD-10 codes within a PBC (when allocating the life-year effects), before applying the QALY ratios associated with each ICD-10 code (see footnote l reporting results using weights based on the size of the population).

As all the analysis in this section seeks to use the estimated mortality and life-year effects as a surrogate for a more complete measure of likely health effects, it is the cost per QALY threshold for all 23 PBCs that is most relevant. As expected, this threshold (£11,638), is lower than a cost per QALY threshold based only the QALY effects (£21,047 and £26,441 in *Table 135* that assumes no effects of NHS expenditure on QoL itself). This difference gives some indication of the relative importance of QALY effects due to avoidance of premature death and the QALY effects of avoiding disability during disease. *Table 144* reports how the estimated QALY effects for each PBC can be decomposed into that part associated with QALY effects and that part associated with 'pure' QoL effects. These results appear credible for the first 11 PBCs, where those for which mortality is the major concern have a much greater share of total QALY effects associated with avoidance of premature death (e.g. PBCs 2 and 10) compared with those where QoL is the major concern (e.g. PBC 7).

The ratios of QALYs to YLL due to disease in those PBCs where outcome elasticities could not be estimated cannot be used to inform estimates of the threshold because there are no estimated life-year effects with which to apply the ratios. Therefore, as in previous sections, the estimated effect of expenditure on health for the 11 PBCs with outcome elasticities is applied to the estimated changes in PBC expenditure for the other 12 PBCs (excluding GMS for the reasons given in *Summary of cost per life-year estimates*), i.e. assuming that the health effects that can be observed from a change in expenditure will be similar to those that cannot. However, the use of QALY ratios also implies that the share of total health effects between QALY effects and that part associated with 'pure' QoL effects are also similar to those PBCs with estimated outcome elasticities. Summing the different types of health effects across these 11 PBCs suggests that 50% is due to avoidance of premature death and 50% due to avoidance of disability. This is clearly not credible when applied to the other PBCs (e.g. mental health, vision and hearing are likely have a much greater share of total health effects associated with QoL effects and very little associated with premature mortality).

TABLE 142 Summary of the QALY threshold using ratios

	Cost per QALY threshold (£)		
PBC scenario	(1) DALY ratios	(2) Adjusted DALY ratios	(3) QALY ratios (HODaR and MEPS)
All big four programmes	5402	6419	5990
11 PBCs (with mortality)	9958	11,718	10,297
All 23 PBCs	11,254	13,244	11,638[a]

a Preferred analysis.

TABLE 143 Breakdown of the QALY threshold using ratios by PBC

PBC		(1) Change in spend (£M)	Adjusted DALY ratios		QALY ratios (HODaR and MEPS)	
			(2) Change in QALY	(3) Cost per QALY gained (£)	(4) Change in QALY	(5) Cost per QALY gained (£)
2	Cancer	19	1763	10,871	1699	11,283
10	Circulatory problems	33	7677	4334	6713	4956
11	Respiratory problems	22	2379	9375	3215	6937
13	Gastrointestinal problems	17	2396	6886	3605	4577
All big four programmes				*6419*		*5990*
1	Infectious diseases	8	21	388,430	27	305,724
4	Endocrine problems	18	1077	16,396	2036	8673
7	Neurological problems	17	296	58,158	342	50,295
17	Genitourinary problems	32	15	2,158,296	12	2,623,379
16	Trauma and injuries	10	0	N/A	0	N/A
18 + 19	Maternity and neonates	8	125	64,173	273	29,327
First 11 PBCs				*11,718*		*10,297*
3	Disorders of blood	11	956	11,718	1087	10,297
5	Mental health disorders	204	17,423	11,718	19,828	10,297
6	Learning disability	31	2627	11,718	2990	10,297
8	Problems of vision	24	2063	11,718	2348	10,297
9	Problems of hearing	6	546	11,718	621	10,297
12	Dental problems	23	2005	11,718	2282	10,297
14	Skin	11	897	11,718	1021	10,297
15	Musculoskeletal system	15	1291	11,718	1469	10,297
20	Poisoning and adverse effects	4	375	11,718	426	10,297
21	Healthy individuals	18	1565	11,718	1781	10,297
22	Social care needs	68	5769	11,718	6566	10,297
23	Other	78	0	N/A	0	N/A
	All 23 PBCs			*13,244*		*11,638*

N/A, not applicable.

TABLE 144 Decomposing estimated QALY effects by PBC

PBC		QALY change (total)	QALY change (death)	% QALY gained	
				Due to avoidance of premature death	Due to avoidance of disability while alive
2	Cancer	1699	1641	97	3
10	Circulatory	6713	4856	72	28
11	Respiratory	3215	923	29	71
13	Gastrointestinal	3605	1193	33	67
1	Infectious diseases	27	11	40	60
4	Endocrine	2036	323	16	84
7	Neurological	342	52	15	85
17	Genitourinary	12	6	52	48
16	Trauma and injuries	0	0	N/A	N/A
18 + 19	Maternity and neonates	273	15	6	94
3	Disorders of blood	1087	547	50	50
5	Mental health	19,828	9979	50	50
6	Learning disability	2990	1505	50	50
8	Problems of vision	2348	1181	50	50
9	Problems of hearing	621	313	50	50
12	Dental problems	2282	1148	50	50
14	Skin	1021	514	50	50
15	Musculoskeletal	1469	739	50	50
20	Poisoning and adverse events	426	215	50	50
21	Healthy individuals	1781	896	50	50
22	Social care needs	6566	3304	50	50
23	Other	0	0	N/A	N/A

N/A, not applicable.

By comparing the change in QALYs in each PBC [that originates cost per QALY threshold estimates, column (2) in *Table 145*], with the corresponding change in YLL [see column (6) in *Table 116*], we can infer the implied QALY to YLL ratio in each of the PBCs with a mortality signal. These are shown in *Table 145*. The QALY to YLL ratio implied by the analysis using QALY ratios for all 11 PBCs with outcome elasticities is 1.52, which suggests that every life-year is associated with 1.52 QALYs on average across these PBCs. However, this implied QALY ratio differs across these PBCs, ranging from 0.79 in PBC 2 to 15.05 in PBC 18 + 19 [see column (4) of *Table 145*]. It should be noted that the implied QALY ratio of 1.33 for the 11 PBCs with outcome elasticities is a ratio of QALYs to unadjusted YLL. The proportion of total QALY effects due to premature deaths for the same PBCs (50% in *Table 144*) also implies a ratio – equal to two. However, this is a ratio of total QALY effects to quality-adjusted YLL. The difference between these two ratios is the denominator (i.e. quality-adjusted YLL are lower than unadjusted YLL).

The problem is that using QALY to YLL ratios means that much of the information that is available about the other 12 PBCs cannot be used to inform the estimates of the cost per QALY threshold. Fortunately, the sources of information on which the ratios are based also provide much of the information required to calculate the QALY burden of disease in these areas. *Using estimates of the quality-adjusted life-year burden of disease* explores how measures of burden can be used to estimate a cost per QALY threshold that captures the likely effects of a change in expenditure on all aspects of health while using all the information that is available about all the PBCs.

TABLE 145 Implied QALY to YLL ratios

PBC		Adjusted DALY ratios			QALY ratios (HODaR and MEPS)		
		(1) Implied QALY per YLG	(2) Implied QALY per excess death averted	(3) Implied QALY per PBC death averted	(4) Implied QALY per YLG	(5) Implied QALY per excess death averted	(6) Implied QALY per PBC death averted
2	Cancer	0.82	11.58	8.48	0.79	11.16	8.17
10	Circulatory problems	1.20	12.51	6.20	1.05	10.94	5.42
11	Respiratory problems	1.96	18.09	2.04	2.65	24.45	2.76
13	Gastrointestinal problems	1.54	23.02	14.49	2.31	34.63	21.80
All big four programmes		*1.26*	*14.20*	*5.12*	*1.35*	*15.21*	*5.49*
1	Infectious diseases	1.56	20.64	8.30	1.98	26.22	10.54
4	Endocrine problems	2.62	35.61	19.84	4.95	67.31	37.51
7	Neurological problems	4.56	61.99	27.90	5.27	71.69	32.26
17	Genitourinary problems	1.75	14.56	2.98	1.44	11.98	2.45
16	Trauma and injuries	N/A	N/A	N/A	N/A	N/A	N/A
18 + 19	Maternity and neonates	6.88	511.33	511.33	15.05	1118.85	1118.85
First 11 PBCs		*1.33*	*15.16*	*5.53*	*1.52*	*17.26*	*6.29*

N/A, not applicable.

Using estimates of the quality-adjusted life-year burden of disease

In this section we use estimates of the QALY burden of disease to infer QALY effects in those PBCs where the mortality effects of changes in expenditure can be observed, and extrapolate the estimated proportionate effects to those PBCs where the health effects of changes in expenditure cannot be observed. The estimated proportionate effect of change in expenditure on the life-year burden of disease in the 11 PBCs where mortality-based outcome elasticities could be estimated are applied to measures of QALY burden in each of these PBCs (i.e. effects on the mortality burden of disease are used as a surrogate for effects on QALY burden). The proportionate effect on burden of disease due to the change in expenditure across these PBCs can then be applied to measures of QALY burden in the other 11 PBCs where mortality effects could not be estimated (i.e. the observed effects of changes in expenditure on burden of disease is extrapolated to the other PBCs where health effects cannot be observed). In this way, we can use all the information available about the mortality and QoL effects of the different types of disease that make up each PBC, particularly those where mortality-based outcome elasticities are not available. Applying a proportionate effect to measures of QALY burden of disease is equivalent to assuming that any effects on life-years are lived at QoL that reflects a proportionate improvement to the QoL with disease.[m] It also allows QoL effects of changes in expenditure to be included; also based on proportionate improvement in the QoL with disease.

In *Adjusting life-years for quality-of-life*, each YLG could be assumed to be lived in full health, lived in a QoL that reflects age and gender norms of the general population or lived in a QoL that reflects the original disease state. Applying an estimated proportionate effect on the life-year burden of disease to measures of QALY burden of disease implies a proportionate improvement in the QoL with disease applied to any life-year effects. Therefore, basing estimates on measures of QALY burden provides a more conservative estimate of the QALY effects of changes in mortality than the best estimate reported in *Adjusting life-years for quality-of-life*, which was based on QoL norms.

Previously, in sections up to *Using ratios of quality-adjusted life-years to years of life lost* (corresponding *to Chapter 3* and *Chapter 4*, *From mortality to life-years*, *Adjusting life-years for quality-of-life* and *Using ratios of quality-adjusted life-years to years of life lost* of main report), expenditure elasticities were not estimated for the other 11 PBCs where outcome elasticities could not be estimated because the same health effect of changes in expenditure was assumed (i.e. it did not matter how changes in expenditure were allocated between them). Given expenditure elasticities were only estimated for PBC 23 and the 11 PBCs where outcome elasticities could be estimated, in analyses up to *Using ratios of quality-adjusted life-years to years of life lost* the remaining change in total spend was assigned to the other 11 PBCs. As a consequence, proportionally more of the share of a change in total spend was allocated to these other PBCs in previous sections [see column (3) of *Table 108*]. However, in this section it does matter how the remaining change in expenditure is allocated between the other 11 PBCs as they have different QALY burdens so different implied health effects of expenditure. Therefore, expenditure elasticities are estimated for all 23 PBCs [see column (2) *of Table 108*]. However, it is not possible to estimate expenditure equations for all 23 PBCs simultaneously, so the 23 independently estimated expenditure elasticities do not account for all of the change in overall spend (i.e. the sum of changes in PBC expenditure based on the estimated PBC expenditure elasticities accounts for less than a 1% change in total spend). This remaining change in total spend is allocated between all 23 PBCs reflecting their relative share of changes in expenditure based on their estimated expenditure elasticities [see column (4) of *Table 108*].

The total QALY burden of disease for the population with disease in a particular year includes (i) the quality-adjusted YLL due to all the disease-related mortality that could occur in this population over their remaining duration of disease; and (ii) the reduction in QoL while alive also for their remaining disease duration. These components of burden represent, respectively, the QALYs lost due to premature death ($QALYl_{death}$) and the QALYs lost while alive ($QALYl_{alive}$) as a consequence of disease.

$$Burden = QALYl_{death} + QALYl_{alive} \quad (28)$$

However, applying the estimated proportionate effects on mortality and life-years to such a measure of total burden would provide an estimate of the effects of a change in expenditure, not just in 1 year, but in all the remaining years of disease for the population at risk in that year. Recall from *From mortality to life-years* that we have adopted the conservative assumption that changes in expenditure will only have health effects in 1 year for the population with disease in that year. Therefore, it is not a measure of total burden that is required, but a measure of the QALY burden of disease during 1 year for the population with disease (prevalent and incident) in that year. The estimated outcome elasticities can then be appropriately (and directly) applied to this measure of burden. Of course, it would be possible to solve for a lower outcome elasticity that could be applied to total burden which would return the required estimate of total QALY effects restricted to 1 year.

The information from GBD used to derive QALY ratios in *Using estimates of the quality-adjusted life-year burden of disease* includes information about the YLL and duration of disease for those incident to a U-code, i.e. the measure of QALY burden from the information included in the ratios is a measure of the total burden of the disease but only for the population that is incident (rather than the total population with disease) in 1 year. Assuming that incidence is stable over the disease duration this is also equivalent to the QALY burden of disease during 1 year for the population with disease (i.e. those that are incident and prevalent) in that year. This is valid as long as estimates of the QoL decrement of disease from HODaR and MEPS are assumed representative of average effects across those earlier (incident) and later (prevalent) in their disease duration.

However, in moving from ratios to absolute measures of burden it becomes more important to examine and then adjust for any inconsistency between information about YLL and size of the incident population from GBD (which is available by U-codes and can be mapped to ICD-10 codes), and the information about net YLL and observed deaths for each PBC based on ONS data as described in *Summary of the cost per quality-adjusted life-year threshold based only on mortality effects* (*Table 146*).

There are a number of reasons for the potential inconsistencies: (i) GBD is based on earlier years of mortality data; (ii) the imprecision of mapping from U-codes to PBC via ICD-10 codes; and (iii) the YLL reported in GBD are based on LE at the age of death (see *Adjusting life-years for quality-of-life* and

TABLE 146 Comparing deaths and YLL from ONS and GBD

		Deaths			YLL		
PBC		(1) Excess deaths ONS	(2) All deaths ONS	(3) All deaths GBD	(4) Adjustment factor (deaths)	(5) Net estimates ONS	(6) Total YLL GBD	(7) Adjustment factor (YLL)
1	Infectious diseases	2797	6958	1408	4.94	36,962	25,142	1.47
2	Cancer	95,715	130,810	140,124	0.93	1,347,184	1,932,637	0.70
4	Endocrine	3769	6765	7509	0.90	51,225	95,401	0.54
7	Neurological	6909	15,353	12,854	1.19	93,917	164,796	0.57
10	Circulatory	79,218	159,852	178,454	0.90	823,768	1,750,608	0.47
11	Respiratory	7386	65,446	67,441	0.97	68,030	594,529	0.11
13	Gastrointestinal	15,199	24,147	28,329	0.85	227,703	396,829	0.57
17	Genitourinary	2172	10,625	8606	1.23	18,127	77,338	0.23
18 + 19	Maternity and neonates	226	226	2211	0.10	16,801	149,868	0.11
Total		*213,391*	*420,182*	*446,936*	*0.94*	*2,683,717*	*5,187,148*	*0.52*

Including quality-of-life effects during disease) and will overestimate the net YLL. The YLL by U-code, reported in GBD, that are mapped to ICD-10 codes are adjusted by these proportionate differences [see column (7) of *Table 146*] to ensure that the YLL associated with all contributing ICD-10 codes are consistent with (and do not overestimate) the net YLL for the PBC as a whole. The variation across ICD-10 codes in the adjusted QALY burden associated with mortality gains (for the population with disease in a particular year) is depicted in column (2) of *Table 147*.

It is QALY burden per patient with disease in a particular year that is reported in *Table 147*, including the median and range across the ICD-10 codes contributing to each PBC. Such measure of burden considers QoL burden while alive in 1 year and mortality burden for the same time period. Note that mortality effects of disease in 1 year can lead to the loss of more than 1 life-year, and, for this reason, burden due to premature death (and consequently overall burden) may assume values bigger than 1. Burden values in *Table 147* reflect variation across ICD-10 codes and should not be misinterpreted as the 'average' QALY burden for the PBC, as this depends on how PBC effects are allocated to ICD-10 codes and the 'average'

TABLE 147 Variation across ICD-10 codes of the QALY burden of disease for a patient with disease in a particular year

PBC		Median [5th to 95th percentile]		
		(1) Burden while alive	(2) Burden due to premature death	(3) Burden
1	Infectious diseases	0.47 [0.00 to 0.82]	0.25 [0.11 to 42.87]	0.72 [0.72 to 42.87]
2	Cancers and tumours	0.09 [0.00 to 0.10]	2.82 [0.51 to 5.11]	2.92 [0.58 to 5.11]
3	Disorders of blood	0.05 [0.05 to 0.07]	0.01 [0.01 to 0.03]	0.06 [0.06 to 0.09]
4	Endocrine	0.10 [0.00 to 0.17]	0.01 [0.01 to 4.82]	0.11 [0.11 to 4.82]
5	Mental health	0.10 [0.07 to 0.22]	0.02 [0.00 to 0.04]	0.12 [0.07 to 0.26]
6	Learning disability	0.10 [0.06 to 0.10]	0.02 [0.00 to 5.34]	0.12 [0.10 to 5.41]
7	Neurological	0.27 [0.00 to 0.37]	0.02 [0.02 to 22.79]	0.29 [0.25 to 22.79]
8	Vision	0.05 [0.00 to 0.06]	0.00 [0.00 to 20.99]	0.05 [0.03 to 20.99]
9	Hearing	0.05 [0.00 to 0.05]	0.00 [0.00 to 20.99]	0.05 [0.00 to 20.99]
10	Circulation	0.09 [0.09 to 0.19]	0.37 [0.06 to 0.39]	0.48 [0.18 to 0.56]
11	Respiratory system	0.14 [0.00 to 0.21]	0.01 [0.00 to 5.17]	0.15 [0.00 to 5.18]
12	Dental	0.03 [0.01 to 0.03]	0.01 [0.00 to 0.01]	0.04 [0.01 to 0.04]
13	Gastrointestinal system	0.10 [0.00 to 0.18]	0.05 [0.00 to 23.67]	0.15 [0.00 to 23.67]
14	Skin	0.06 [0.00 to 0.06]	0.02 [0.02 to 20.99]	0.08 [0.08 to 20.99]
15	Musculoskeletal system	0.10 [0.00 to 0.10]	0.02 [0.00 to 20.99]	0.12 [0.06 to 20.99]
16	Trauma and injury	N/A	N/A	N/A
17	Genitourinary system	0.11 [0.00 to 0.13]	0.04 [0.00 to 8.90]	0.15 [0.05 to 8.90]
18	Maternity	0.01 [0.00 to 0.01]	0.00 [0.00 to 4.68]	0.01 [0.00 to 4.68]
19	Conditions of neonates	0.00 [0.00 to 0.00]	0.03 [0.02 to 0.03]	0.03 [0.02 to 0.03]
20	Poisoning and adverse events	0.03 [0.00 to 0.06]	0.00 [0.00 to 18.63]	0.03 [0.02 to 18.63]
21	Healthy individuals	0.05 [0.05 to 0.05]	0.01 [0.01 to 0.01]	0.06 [0.06 to 0.06]

N/A, not applicable.

Note

QALY burden of disease reflects burden while alive in 1 year and mortality burden in 1 year. Any mortality effects of disease in 1 year can lead to the loss of more than 1 life-year, and for this reason burden due to premature death may assume values bigger than 1.

burden for groups of PBCs depends on how a change in overall expenditure is shared between them (i.e. the expenditure elasticities estimated for each PBC in *Appendix 2*).

Due to the earlier years of data and imprecision in mapping from U-codes to ICD-10 codes there might also be some inconsistency in estimates of the total incidence of disease for a PBC. Insofar as disease-related mortality risk is stable, the same number of deaths should be observed in GBD and ONS data for the same at risk population. The PBC deaths recorded in GBD and those observed in ONS data [see columns (2) and (3) in *Table 146*] are similar but nonetheless the proportionate difference is used to adjust the scale of QoL burden while alive based on GBD information (equivalent to adjusting estimates of incidence). Notable exceptions are PBC 1 and PBC 18 + 19 where the discrepancies are likely to be due to imperfect mapping from U-code to PBC via ICD-10 codes. Summaries of the ICD-10-specific values of the adjusted burden of disease while alive are depicted in column (1) of *Table 147*. Total burden (for the population with disease in a particular year) is the sum of the two components of burden (*Table 148* presents a few examples for illustration).

The implications for the cost per QALY threshold of using information about the QALY burden of disease for all PBCs, rather than QALY ratios for those where an outcome elasticity can be estimated, are reported summarily in *Table 149* and in detail in *Table 150*. The QALY effects of a change in PBC expenditure are a weighted average of the QALY effects within each of the ICD-10 codes that contribute to the PBC. The figures reported in column 2 (*Table 149*) are based on weighing the effects at ICD-code level by the proportion of the total PBC population within each contributing ICD-10 code, rather than the contribution to variance in HES costs.[n]

The cost per QALY threshold for the 11PBCs with outcome elasticities is a little lower using a measure of QALY burden (£5128) rather than the QALY ratios (£10,297) described in *Using ratios of quality-adjusted life-years to years of life lost*. This is in part because the way GBD calculates YLL overestimates net YLL

TABLE 148 Examples of QALY burden of disease for the population with disease in a particular year

U-code	QALY burden	(QALY $lost_{death}$ + QALY $lost_{alive}$)
U037 (other infectious diseases)[a]	0.20	(0.09 + 0.11)
U016 (tetanus)	2.73	(2.73 + 0.00)
U061 (mouth and oropharynx cancers)	2.97	(2.87 + 0.10)
U141 (spina bifida)	0.65	(0.18 + 0.46)

a Note that differential adjustments have been made to YLL (affecting QALY $lost_{death}$) and to the incidence (affecting QALY $lost_{alive}$), thus implied ratios from these burden estimates may differ from ratios presented in *Using ratios of quality-adjusted life-years to years of life lost*.
QALY burden of disease reflects burden while alive in 1 year and mortality burden in 1 year. Any mortality effects of disease in 1 year can lead to the loss of more than 1 life-year, and for this reason burden due to premature death may assume values bigger than 1.

TABLE 149 Summary of the cost per QALY threshold

	Cost per QALY gained (£)[a]	
PBC grouping	(1) QALY ratios (HODaR and MEPS)	(2) QALY burden (HODaR and MEPS)
All big four programmes	5990	3036
11 PBCs (with mortality)	10,297	5128
All 23 PBCs	11,638	10,187[a]

a Preferred analysis.

TABLE 150 Breakdown of the cost per QALY threshold

PBC		(1) Change in spend (£M)	QALY ratios (HODaR and MEPS) (2) Change in QALY	QALY ratios (HODaR and MEPS) (3) Cost per QALY gained (£)	QALY burden (HODaR and MEPS) (4) Change in QALY	QALY burden (HODaR and MEPS) (5) Cost per QALY gained (£)
2	Cancer	19	1699	11,283	2121	12,772
10	Circulatory problems	33	6713	4956	8347	5631
11	Respiratory problems	22	3215	6937	28,072	1123
13	Gastrointestinal problems	17	3605	4577	3922	5944
All big four programmes				*5990*		*3036*
1	Infectious diseases	8	27	305,724	74	158,349
4	Endocrine problems	18	2036	8673	6905	3613
7	Neurological problems	17	342	50,295	1361	17,844
17	Genitourinary problems	32	12	2,623,379	34	1,320,516
16	Trauma and injuries	10	0	N/A	0	N/A
18 + 19	Maternity and neonates	8	273	29,327	14	813,578
First 11 PBCs				*10,297*		*5128*
3	Disorders of blood	11	1087	10,297	1215	6814
5	Mental health disorders	204	19,828	10,297	10,878	13,876
6	Learning disability	31	2990	10,297	207	109,806
8	Problems of vision	24	2348	10,297	561	31,858
9	Problems of hearing	6	621	10,297	1168	4047
12	Dental problems	23	2282	10,297	578	30,030
14	Skin	11	1021	10,297	103	75,158
15	Musculoskeletal system	15	1469	10,297	1005	11,129
20	Poisoning and adverse effects	4	426	10,297	42	76,909
21	Healthy individuals	18	1781	10,297	40	336,325
22	Social care needs	68	6566	10,297	0	N/A
23	Other	78	0	N/A	0	N/A
All 23 PBCs				*11,638*		*10,187*

N/A, not applicable.

(which accounts for counterfactual deaths, as detailed in *Summary of the cost per quality-adjusted life-year threshold based only on mortality effects*). This will make no difference to the first term in the QALY ratio (R_{death}) used in *Using ratios of quality-adjusted life-years to years of life lost* as an overestimate of YLL affects both denominator and numerator of the ratio. However, the second term (R_{alive}) is likely to be underestimated. Therefore, the ratios will tend to underestimate the QALY effects of expenditure and overestimate the cost per QALY threshold (see *Table 149*). We are able to adjust the GBD-based measure of QALY burden for this overestimation in calculating the QALY threshold reported in column (2) of *Table 149*.

As the purpose of this section is to use the estimated mortality and life-year effects as a surrogate for a more complete measure of likely health effects, it is the cost per QALY threshold for all 23 PBCs that is of most relevance. The cost per QALY threshold for all 23 PBCs is based on applying the proportionate effects on the QALY burden of disease, based on the observed effects of changes in expenditure on mortality in the 11 PBCs with outcome elasticities,[o] to the QALY burden of disease in the other PBCs. This generates a higher cost per QALY threshold (£10,187) than the one based only on the 11 PBCs with outcome elasticities (£11,638). The reason is that the QALY burden of disease in the other PBCs is, in general, lower than the QALY burden of disease across those PBCs where outcome elasticities can be estimated (see *Table 147*).

Therefore, applying the same proportionate effects to a lower QALY burden generates a smaller health effect of a change in expenditure.[p] In essence, the difference between these estimates is that in column (1) of *Table 149* the absolute effect on health associated with an absolute change in expenditure is extrapolated to the other PBCs, whereas in column (2) of *Table 149* it is the relative effect on health of an absolute change in expenditure that is extrapolated. As we know that QALY burden differs between (and within) PBCs, and especially between the groups of PBCs with and without estimated outcome elasticities (see *Table 147*), it is the values based on QALY burden in column (2) of *Table 149* that are regarded as most credible and represent our central or best estimate.

A detailed breakdown of changes in expenditure and changes in QALYs across all PBCs is shown in *Table 150*, where the analysis is based on QALY ratios and on QALY burden of disease. A comparison of these values suggests that QALY effects for the other PBCs are generally lower and therefore the cost per QALY for each of these PBCs are in general higher when based on a proportionate effect on QALY burden. Of course, we have not directly observed QoL effects in these PBCs but inferred them from the proportionate effects that we can observe. Insofar as investment and disinvestment opportunities in these PBCs might have been more valuable (offered greater improvement in QoL) than suggested by the implied PBC thresholds, then overall QALY effects will tend to be underestimated and the cost per QALY threshold overestimated.

For the reasons discussed in previous sections, we regard all the costs per QALY threshold reported in column (2) of *Table 149* to be on balance conservative with respect to overall health effects of a change in expenditure. However, the estimate of £10,187 is based on an extrapolation of the proportionate effects to measures of burden on these PBCs, rather than observations of the direct impact of changes in expenditure on QoL in these types of disease. This is especially important in PBC 5, mental health disorders, which accounts for a large proportion of the change in overall expenditure (22%) and where a review of the evidence suggests that the investment and disinvestment opportunities in this PBC may have been more valuable than the implied PBC cost per QALY of £13,876 (see *Addendum 3: characterisation of the investment and disinvestment decisions in mental health – depression and schizophrenia*). The lower cost per QALY threshold for the 11 PBCs with outcome elasticities (£5128) might be regarded as more secure in this respect, but they only account for a proportion (38%) of any change in overall expenditure (see *Table 155*).

Table 151 reports how the estimated QALY effects based on measures of QALY burden for each PBC can be decomposed into that part associated with life-year effects adjusted for quality and that part associated with 'pure' QoL effects. These results are similar to those reported in *Table 144* which were based on QALY ratios for the 11 PBCs with an estimated outcome elasticity. Those PBCs for which mortality is the major concern have a much greater share of total QALY effects associated with avoidance of premature death (e.g. PBCs 2 and 10) compared with those where QoL is the major concern (e.g. PBC 7). The differences tend to favour QALYs gained though avoidance of disability, which reflects the underestimation of the effects on 'pure' QoL when using QALY ratios based on estimates of YLL from GBD (see the discussion above). The exceptions are PBC 1 and PBC 18 + 19. The reason is that there are significant adjustments made based on differences in observed and recorded mortality (to adjust for differences in recording), as well as differences in YLL due to the GBD method of calculation (see *Table 146*).

The implied QALY per YLG and death averted are reported in *Table 152*. As expected, the implied QALY per PBC death averted across all 11 PBCs with outcome elasticities is higher (12.6 QALYs) than reported in *Using ratios of quality-adjusted life-years to years of life lost* (6.3 QALYs) because of the previous bias against QoL effects.

TABLE 151 Decomposing estimated QALY effects by PBC

PBC		(1) QALY change (total)	(2) QALY change (death)	% QALY gained	
				(3) For premature death	(4) For disability while alive
2	Cancer	2121	1968	93	7
10	Circulatory	8347	5727	69	31
11	Respiratory	28,072	1072	4	96
13	Gastrointestinal	3922	1446	37	63
1	Infectious diseases	74	13	18	82
4	Endocrine	6905	380	5	95
7	Neurological	1361	60	4	96
17	Genitourinary	34	8	22	78
16	Trauma and injuries	0	0	N/A	N/A
18 + 19	Maternity and neonates	14	10	69	31
3	Disorders of blood	1215	62	5	95
5	Mental health	10,878	949	9	91
6	Learning disability	207	41	20	80
8	Problems of vision	561	22	4	96
9	Problems of hearing	1168	9	1	99
12	Dental problems	578	1	0	100
14	Skin	103	38	37	63
15	Musculoskeletal	1005	50	5	95
20	Poisoning and adverse events	42	7	16	84
21	Healthy individuals	40	6	16	84
22	Social care needs	0	0	N/A	N/A
23	Other	0	0	N/A	N/A

N/A, not applicable.

TABLE 152 Implied QALY per excess death averted: using burden

PBC		(1) QALY per YLG	(2) Implied QALY per excess death averted	(3) Implied QALY per PBC death averted
2	Cancer	0.70	9.86	7.21
10	Circulatory problems	0.93	9.63	4.77
11	Respiratory problems	16.40	151.10	17.05
13	Gastrointestinal problems	1.78	26.66	16.78
All big four programmes		2.66	30.02	10.82
1	Infectious diseases	3.83	50.62	20.35
4	Endocrine problems	11.89	161.59	90.04
7	Neurological problems	14.86	202.05	90.92
17	Genitourinary problems	2.85	23.80	4.87
16	Trauma and injuries	N/A	N/A	N/A
18 + 19	Maternity and neonates	0.54	40.33	40.33
First 11 PBCs		*3.05*	*34.65*	*12.63*

N/A, not applicable.

In *Using ratios of quality-adjusted life-years to years of life lost*, the ratios of QALYs to YLL due to disease in those PBCs where outcome elasticities could not be estimated could not be used to inform estimates of the threshold or indicate how any total health effects in these other PBCs are likely to be 'shared' between life-year effects adjusted for quality and that part associated with 'pure' QoL effects (see *Table 144*). By applying the observed proportionate effects of changes in expenditure to measures of QALY burden of disease in these other PBCs the likely share of any effects on QALYs between avoidance of premature mortality and avoidance of disability more closely reflect the nature of these types of diseases (see *Table 151*). As expected, a much greater proportion of QALY effects are associated with QoL during the disease compared with the 11 PBCs where mortality-based outcome elasticities could be estimated. The share of effects in particular PBCs are also much more credible. For example, in PBC 5 (mental health disorders) the overwhelming share of QALY effects are associated with QoL itself and for others, such as PBC 12 (dental problems), PBC 9 (problems of hearing) and PBC 8 (problems of vision), almost all effects are associated with QoL rather than mortality and life-years. For this, and the other reasons discussed above, the analysis based on measures of QALY burden are regarded as the best estimate of a cost per QALY ratio that reflects a more complete picture of the likely health effects of changes in overall expenditure.

Summary of the cost per quality-adjusted life-year threshold

The results of the three sequential steps of analysis described in this appendix are summarised in *Table 153*. In *From mortality to life-years* we explored ways in which the estimated effects on mortality from the econometrics work in *Appendix 2* might be better translated into life-year effects by overcoming some of the limitations of mortality data available at PCT level and taking account of counterfactual deaths. The results of this analysis were reported in *Table 122* and are repeated in column (1) of *Table 153*. These results can be interpreted as cost per QALY thresholds conditional on the assumption that all life-years are lived in full health and the QoL with disease is zero (equivalent to death).

In *Adjusting life-years for quality-of-life* we considered how the estimated life-year effects might be adjusted for the QoL in which they are likely to be lived, taking account of the gender and the age at which life-years are gained or lost (see *Table 135*). The results of this analysis are repeated in *Table 153*, column (2). Finally, in the current section, we explored ways to also take account of the likely effects of changes in expenditure on QoL during disease as well as the effects associated with mortality and life-years

TABLE 153 Summary of cost per QALY threshold estimates

PBC grouping	(1) *Chapter 4, From mortality to life-years* analysis	(2) *Chapter 4, Adjusting life-years for quality-of-life* analysis	(3) *Chapter 4, Including quality-of-life effects during disease* analysis
QoL associated with life extension	1	Norm	
QoL during disease	0	0	Based on burden
Best estimate			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	~4.1	~4.1	~4.1
QALYs per death averted	~4.1	~3.5	~14.9
(1) All big four programmes	£8080	£9631	£3036
(2) 11 PBCs (with mortality)	£15,628	£18,622	£5128
(3) All 23 PBCs	£17,663	£21,047	**£10,187**
Lower bound			
Effect of expenditure on mortality	Remainder of disease duration	Remainder of disease duration	Remainder of disease duration
YLL per death averted	~4.1	~4.1	~4.1
QALYs per death averted	~4.1	~3.5	~14.9
(4) All big four programmes	£3846	£4252	£674
(5) 11 PBCs (with mortality)	£6106	£6852	£860
(6) All 23 PBCs	£6901	£7744	**£1843**
Upper bound			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	2	2	2
QALYs per death averted	~2	~1.9	~7.2
(7) All big four programmes	£16,432	£17,456	£6292
(8) 11 PBCs (with mortality)	£32,387	£34,492	£10,626
(9) All 23 PBCs	£36,604	£38,983	**£21,111**

[see *Table 153*, column (3)]. These estimates provide our central estimate of a cost per QALY threshold, because they make best use of available information while the assumptions required, which on balance are likely conservative with respect to health effects, appear more reasonable than the other alternatives available.[q]

The estimate of £5128 per QALY [see *Table 153*, line (2)] is restricted to the effects of changes in expenditure in the 11 PBCs where outcome elasticities can be estimated. Although this might be regarded as more secure, these PBCs only account for a proportion of the change in overall expenditure [approximately 38%, column (6) in *Table 108*]. The threshold of £10,187 uses the estimated proportionate effects of expenditure on the QALY burden of disease in these PBCs as a surrogate for proportionate effects in the others (i.e. assuming that the effects that can be observed will be similar to those that cannot). As discussed in *Using estimates of the quality-adjusted life-year burden of disease*, there are reasons to suspect that this may underestimate health effects in these PBCs which have most influence on the overall threshold. As in previous sections, no health effects are assigned to PBC 23 (GMS) on the basis that any health effects of this expenditure would be recorded in the other PBCs.[r] Therefore, the best or central estimate of cost per QALY threshold is £10,187 [see *Table 153*, column (3), line (3)].

This estimate reflects changes in undiscounted QALYs associated with changes in expenditure. Although all the health effects of a change in expenditure are restricted to 1 year (so no discounting is necessary) some of the QALY effects of a change in mortality in that year will occur in future years, so in principle should be discounted. However, discounting these life-year effects, even at the higher rate of 3.5% recommended by NICE, only increases the cost per QALY threshold to £10,333 (*Table 154*).

As in previous sections of this chapter, the upper and lower bounds for the cost per QALY thresholds in *Table 153*, column (3) are based on making the necessary assumptions about duration of health effects and how long a death might be averted optimistic (providing the lower bound for the threshold) or conservative (an upper bound for the threshold). The lower bound [see *Table 153*, lines (4)–(6)] is based on assuming that health effects are not restricted to 1 year but apply to the whole of the remaining disease duration of the population at risk in PBCs during 1 year. Although this combines optimistic assumptions, it is possible that at least some part of a change in expenditure may prevent disease so will have an impact on populations that are incident to PBCs in the future. Such effects are not captured in any of the estimates presented in this chapter so all are conservative with respect to this type of health effects of expenditure. The upper bound [*Table 153*, lines (7)–(9)] is based on the combination of assuming that health effects are restricted to 1 year for the population currently at risk and that any death averted is only averted for 2 years (see *Summary of cost per life-year estimates*).

Which programme budget categories matter most?

Which PBCs have the greatest influence on the overall threshold depends, to a large extent, on how a change in overall expenditure is allocated to the different PBCs [*Table 155*, column (1)], i.e. those that account for a greater share of the change in expenditure will tend to have the greater influence.[s]

However, the overall threshold also depends on the proportionate effect of a change in PBC expenditure on the QALY burden associated with the PBC[t] and the scale of the QALY burden (for the population at risk) associated with the type of diseases that make up each PBC.[u] These determine the cost per QALY associated with each PBC [see *Table 155*, column (4)]. The share, attributable to each PBC, of the total health effects of a change in overall expenditure [see *Table 155*, column (2)] is the combined effect of all of these. The proportionate impact on the overall cost per QALY threshold of a 10% change in PBC health effects gives an indication of how sensitive the overall threshold is to the estimate of health effects associated with each PBC [see *Table 155*, column (3)]

Although the 11 PBCs where outcome elasticities could be estimated only account for 38.4% of the change in overall expenditure, they account for 76.3% of the overall health effects. Within this group some PBCs contribute more than others. For example, PBC 11 (respiratory) accounts for a greater share of total health effects and has a higher elasticity (4.22%) than PBC 10 (circulatory), even though it accounts

TABLE 154 Summary of QALY threshold, discounted

	Best estimate (£)	
PBC scenario	(1) Undiscounted	(2) Discounted[a]
(1) All big four programmes	3036	3097
(2) 11 PBCs (with mortality)	5128	5218
(3) All 23 PBCs[b]	10,187	10,333

a Only quality-adjusted net YLL were discounted, and thus QALYs associated with gains in QoL during disease were not. The discounting factor has been calculated by applying a 3.5% discount rate to each year of life lost in the PBCs – the estimate of YLL used was the implied YLL per death averted in each PBC [see column (2) of *Table 121*]. This discounting factor was applied to net YLL, before applying the outcome elasticity to calculate YLL averted.
b In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

TABLE 155 Impact of each PBC on the overall cost per QALY threshold

PBC		(1) % share of change in overall expenditure	(2) % share of total health effects (QALY)	(3) Elasticity of the threshold[a]	(4) PBC cost per QALY (£)
2	Cancer	3.99	3.18	0.32	12,772
10	Circulatory	6.92	12.52	1.25	5631
11	Respiratory	4.64	42.12	4.22	1123
13	Gastrointestinal	3.43	5.89	0.59	5944
1	Infectious diseases	1.74	0.11	0.01	158,349
4	Endocrine	3.67	10.36	1.04	3613
7	Neurological	3.58	2.04	0.20	17,844
17	Genitourinary	6.61	0.05	0.01	1,320,516
16	Trauma and injuries	2.15	0.00	0.00	N/A
18 + 19	Maternity and neonates	1.67	0.02	< 0.01	813,578
3	Disorders of blood	1.22	1.82	0.18	6814
5	Mental health	22.23	16.32	1.63	13,876
6	Learning disability	3.35	0.31	0.03	109,806
8	Problems of vision	2.63	0.84	0.08	31,858
9	Problems of hearing	0.70	1.75	0.18	4047
12	Dental problems	2.56	0.87	0.09	30,030
14	Skin	1.14	0.16	0.02	75,158
15	Musculoskeletal	1.65	1.51	0.15	11,129
20	Poisoning and adverse events	0.48	0.06	0.01	76,909
21	Healthy individuals	2.00	0.06	0.01	336,325
22	Social care needs	7.36	0.00	0.00	N/A
23	Other	16.28	0.00	0.00	N/A

N/A, not applicable.
a Calculated using the effect on the threshold of a 10% increase (or decrease) in QALY change of the PBC.

for a greater part of a change in overall expenditure. The reason is that the cost per QALY associated with changes in expenditure in PBC 11 is lower than PBC 10 and much lower than the overall threshold (so generates more health effects for the same, or even smaller, change in expenditure). The elasticities in *Table 155*, column (3) are instructive (e.g. the elasticity for PBC 11 suggests that even if the health effects of a change in expenditure in this PBC were overestimated by 30% the overall threshold would only increase by 12.7% to £11,477). All other PBCs have much less influence in this respect. Nonetheless, PBC 10 is important compared with others as it does contribute a large share of total health effects and has one of the highest elasticities (1.25%).

The other 12 PBCs, where outcome elasticities could not be estimated, account for the greater part of a change in overall expenditure (61.6%) but only 23.7% of the overall health effects (i.e. the cost per QALYs associated with a change in expenditure in these PBCs are, in general, higher). Of course, we have not directly observed QoL effects in these PBCs but inferred them from the proportionate effects that we can observe. Insofar as investment and disinvestment opportunities in these PBCs might have been more valuable (offered greater improvement in QoL) than suggested by the implied PBC thresholds in *Table 155*, column (4), the overall QALY effects will tend to be underestimated and the overall cost per QALY threshold will be overestimated.

Programme budget category 5 (mental health disorders) accounts for a large proportion of the change in overall expenditure (22.23%), contributes most to the overall health effects (16.32%) and has the highest elasticity (1.63%) compared with these other PBCs. The cost per QALY associated with this PBC (£13,876) is based on an extrapolation of estimated proportionate effects to a population-based measure of QALY burden in this PBC, rather than observations of the direct impact of changes in expenditure on QoL in the types of diseases that make up the PBC. Evidence that is available suggests that the investment and disinvestment opportunities in this PBC may have been more valuable than this implied cost per QALY (see *Addendum 3: characterisation of the investment and disinvestment decisions in mental health – depression and schizophrenia*). A search for evidence about interventions in those ICD-10 codes that contribute most to the PBC (based on prevalence or the contribution to the variance in PBC costs), suggests that pharmacological, psychological and social interventions for depression are all more cost-effective (in general much less than £10,000 per QALY) than the overall threshold, and significantly more valuable than the implied QALY threshold for this PBC. Based on the contribution that each ICD-10 code makes to variance in HES costs across PCTs, it is schizophrenia that contributes most.[v] Although interventions that may have been invested or disinvested in schizophrenia are, in general, less cost-effective (in general less than £24,000 per QALY) than those available for depression, they do not appear any less valuable than the implied cost per QALY of this PBC in *Table 155*.[w]

How uncertain are the estimates?

There are a number of sources of uncertainty which may contribute to an assessment of how uncertain a central or best estimate of the cost per QALY threshold might be. There are three reasons why uncertainty in the estimate of the threshold might be of policy interest: (i) the uncertainty in the parameters that determine the threshold might influence the mean or expected value of the threshold if they have a non-linear relationship to the threshold or when they have a multilinear relationship but are correlated with each other; (ii) the consequences of over- or underestimating the threshold differ so the uncertainty may have an influence on the extent to which a policy threshold (a single value that can be compared to the ICER of a new technology) should differ from the mean or expected value of the central or best estimate; and (iii) in conjunction with other methods of analysis it can indicate the potential value of gathering more information to improve these estimates in the future. Such analysis, known as value of information analysis, has firm foundations in statistical decision theory and has been applied to health-care decisions. A form of these analyses could be applied in subsequent research, ideally capturing some of the other sources of uncertainty. More recently, it has been applied to the decisions faced by NICE when considering if there is sufficient evidence to support the approval of a new technology.[95] Of course, hypothesis testing and the traditional rules of inference associated with it, such as statistical significance, *p*-values and confidence intervals, have no relevance when making unavoidable decisions about policy relevant quantities based on information currently available and the best use thereof.[96]

An assessment of parameter uncertainty

Two sets of parameters are critical to the threshold, the expenditure elasticities estimated for each of the 23 PBCs, and the outcome elasticities estimated for 11 of these. These parameters are estimated with uncertainty, indicated by the standard errors on the relevant coefficients in the econometric analysis detailed in *Appendix 2*. As these statistical models estimate coefficients using normality on the relevant scale, normal distributions can be assigned to each of these estimated coefficients, each with a mean and standard deviation based on the results of the econometric analysis. These distributions represent the uncertainty in the mean estimate of each of the parameters and can be propagated through the various calculations required to estimate the overall cost

per QALY threshold (i.e. through the sequence of analysis detailed in *Adjusting life-years for quality-of-life, Including quality-of-life effects during disease* and *Which programme budget categories matter most?*) using Monte Carlo simulation which randomly samples from the assigned distributions. The use of Monte Carlo simulation in this context is in essence Bayesian, where the standard errors from the frequentist econometric analysis are used to assign normal prior distributions with means equal to the point estimates and a standard deviation equal to the estimated standard errors. This is equivalent to a fully Bayesian analysis with initially uninformative priors which are updated through the analysis of expenditure and mortality data.

The results of each random sample from the Monte Carlo simulation represent one possible realisation of the overall threshold, given the uncertainty in estimates of the mean parameter values that determine it. By repeatedly sampling, a distribution of potential values that the overall threshold might take can be revealed. The results of this simulation are illustrated in *Figure 51* showing a histogram of threshold values, and in *Figure 52* showing the cumulative probability density function for a cost per QALY threshold based only on the 11 PBCs with estimated outcome elasticities and for all 23 PBCs. It represents the probability (on the *y*-axis) that the threshold lies below a particular value.

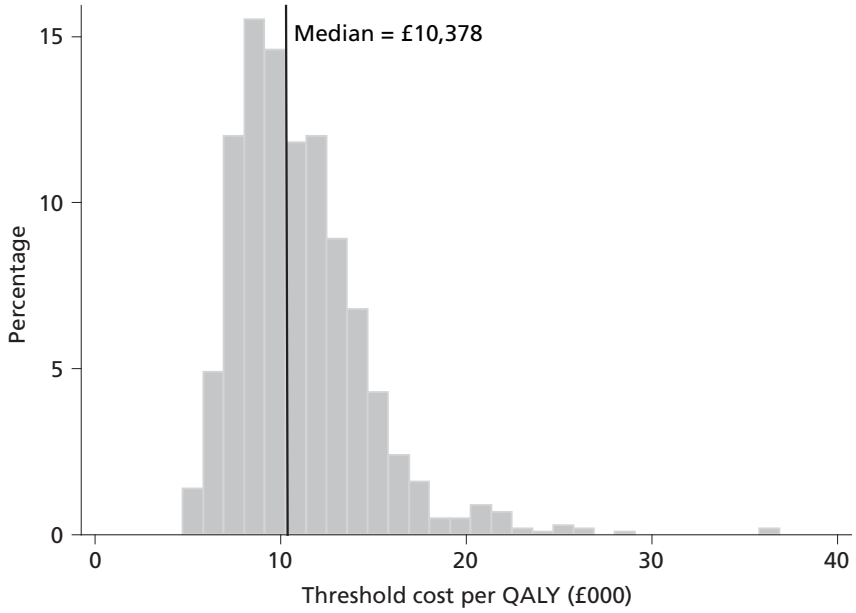


FIGURE 51 Distribution of the cost per QALY threshold (all 23 PBCs).

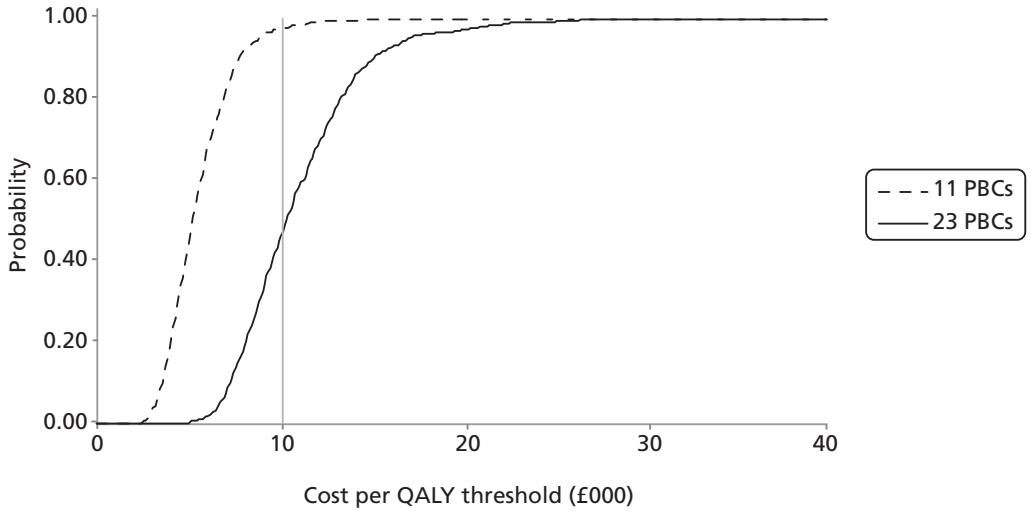


FIGURE 52 Cumulative probability density function for the cost per QALY threshold.

It has already been noted that restricting attention only to changes in expenditure in those 11 PBCs where an outcome elasticity can be estimated results in a much lower estimate of the threshold than considering all changes in expenditure across all PBCs. This lower estimate of £5144 per QALY is much less uncertain but these PBCs only account for 38% of a change in overall expenditure, so it is the higher estimate, for all 23 PBCs, that is of most relevance for policy (see *Summary of the cost per quality-adjusted life-year threshold* and *Which programme budget categories matter most?*). The fact that this estimate is more uncertain simply reflects the quality and quantity of data currently available. As useful analysis should endeavour to faithfully characterise uncertainty in policy relevant quantities, rather than select those quantities or questions for which precise estimates are possible, it is the more uncertain estimate for all 23 PBCs that should be of primary interest. The values that are used to generate *Figure 52* are available in column (2) of *Table 156*. They indicate that the probability that the overall threshold is < £20,000 per QALY is 0.97 and the probability that is < £30,000 is 1.00.

TABLE 156 Uncertainty over the QALY threshold

Scenario	(1) 11 PBCs	(2) All 23 PBCs
Best estimate (deterministic)	£5128	£10,187
Mean estimate (from the simulations)	£5114	£10,092
Threshold value at the probability of (from the simulations)		
2.5%	£2956	£6228
5.0%	£3237	£6744
50.0%	£5250	£10,378
95.0%	£8845	£17,061
97.5%	£10,068	£20,472
Probability (from the simulations) of the threshold being smaller than		
£3000 per QALY	0.03	0.00
£4000 per QALY	0.19	0.00
£5000 per QALY	0.44	0.00
£6000 per QALY	0.66	0.02
£7000 per QALY	0.81	0.07
£8000 per QALY	0.92	0.18
£9000 per QALY	0.96	0.31
£10,000 per QALY	0.97	0.45
£15,000 per QALY	1.00	0.90
£20,000 per QALY	1.00	0.97
£25,000 per QALY	1.00	0.99
£30,000 per QALY	1.00	1.00

Re-estimating the cost per quality-adjusted life-year threshold using 2008 expenditure data

The same methods of analysis can be applied to the econometric analysis of the 2008/9 expenditure and 2008–10 mortality data (see *2008/9 expenditure data and mortality data for 2008/9/10* in *Chapter 3* and *Analysis of programme budgeting expenditure for 2008/9 and mortality data for 2008/9/10* in *Appendix 2*). The differences between the 2006 analysis reported above and the analysis of expenditure in 2008 reported below (*Table 157*) are the (i) total PBC expenditure; (ii) estimated expenditure elasticities; (iii) estimated outcome elasticities; (iv) observed PBC deaths by age and gender; and (v) LE by age and gender. The other information about QoL norms (see *Adjusting age-related quality-of-life for disease decrements*), disease-related decrements (see *Summary of the cost per quality-adjusted life-year threshold based only on mortality effects*) and the information from GBD about incidence (by age and gender) and duration of disease (see *Including quality-of-life effects during disease*) remain unchanged between 2006 and 2008.

It should be noted that important improvements were made to the classification and collection of PBC expenditure data that took place after the 2006 data were collected. Therefore, the differences in threshold estimates for 2006 and 2008 partly reflect this (see *Chapter 3, Comparing the cost of life-year estimates associated with different data sets* and *Comparing the cost of life-year estimates associated with different data sets* in *Appendix 2*) so should not be overinterpreted. The results of the analysis of 2007 and 2008 expenditure are comparable in this respect, providing insights into how the threshold might change over time and with changes in the overall budget. For the purposes of this methodological research the 2008 expenditure and 2008–10 mortality data were the latest to be analysed.

From mortality to life-years

In this section we summarise the calculation of net YLL, which take account of the fact that some of the observed deaths would have occurred anyway (had the same population not been at risk in the particular PBC) when estimating YLL (unobserved counterfactual deaths). In summary, to obtain net YLL, all observed deaths – both those that occur below and those that occur above LE (*Table 158*) – are taken into account. Those deaths occurring below LE generate YLL and those that occur at ages above LE generate YLG. By subtracting YLG from YLL to generate net YLL we take account of the fact that not all deaths below LE are excess deaths but some deaths above LE are.

The estimates of net YLL calculated considering estimates of the LE for each PBC are detailed in *Table 159*.

The impact on the cost per life-year threshold is summarised in column (2) of *Table 160*, and a detailed breakdown is shown in *Table 161*.

TABLE 157 Outcome and spend elasticities (2008)

PBC		(1) Total spend 2008/9 (£M)	Spend elasticities			Change in spend (£M) (% share)		(7) Outcome elasticities[a]
			(2) Unadjusted	(3) Analysis up to *Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* (and *Appendix 3*)	(4) Analysis in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* (and *Appendix 3*)	(5) Analysis up to *Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* (and *Appendix 3*)	(6) Analysis in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* (and *Appendix 3*)	
2	Cancer	4843	0.525	0.525	0.724	25 (3.2)	35 (4.5)	0.307
10	Circulatory	6655	0.648	0.648	0.894	43 (5.5)	59 (7.6)	1.319
11	Respiratory	3994	0.652	0.652	0.900	26 (3.3)	36 (4.6)	1.808
13	Gastrointestinal	3989	0.456	0.456	0.629	18 (2.3)	25 (3.2)	1.364
All big four programmes		*19,481*				*113 (14.4)*	*156 (19.8)*	
1	Infectious diseases	1201	1.545	1.545	2.132	19 (2.4)	26 (3.3)	0.504
4	Endocrine	2222	0.484	0.484	0.668	11 (1.4)	15 (1.9)	1.170
7	Neurological	3466	0.980	0.980	1.352	34 (4.3)	47 (6)	0.417
17	Genitourinary	3779	0.697	0.697	0.962	26 (3.4)	36 (4.6)	1.615
16	Trauma and injuries	3255	1.344	1.344	1.854	44 (5.6)	60 (7.7)	–
18 + 19	Maternity and neonates	3978	0.975	0.975	1.345	39 (4.9)	54 (6.8)	0.125
First 11 PBCs		*37,382*				*285 (36.3)*	*393 (50.1)*	
3	Disorders of blood	998	1.171	2.291	1.616	23 (2.9)	16 (2.1)	–
5	Mental health	9794	1.036	2.027	1.429	198 (25.3)	140 (17.9)	–
6	Learning disability	2874	0.205	0.401	0.283	12 (1.5)	8 (1)	–
8	Vision	1688	0.654	1.279	0.902	22 (2.8)	15 (1.9)	–

PBC		(1) Total spend 2008/9 (£M)	Spend elasticities			Change in spend (£M) (% share)		(7) Outcome elasticities[a]
			(2) Unadjusted	(3) Analysis up to *Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* (and *Appendix 3*)	(4) Analysis in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* (and *Appendix 3*)	(5) Analysis up to *Chapter 4, Using ratios of quality-adjusted life-years to years of life lost* (and *Appendix 3*)	(6) Analysis in *Chapter 4, Using estimates of the quality-adjusted life-year burden of disease* (and *Appendix 3*)	
9	Hearing	417	1.191	2.330	1.643	10 (1.2)	7 (0.9)	–
12	Dental	3198	0.513	1.003	0.708	32 (4.1)	23 (2.9)	–
14	Skin	1657	0.674	1.318	0.930	22 (2.8)	15 (2)	–
15	Musculoskeletal	4081	0.505	0.988	0.697	40 (5.1)	28 (3.6)	–
20	Poisoning and adverse events	938	0.562	1.099	0.775	10 (1.3)	7 (0.9)	–
21	Healthy individuals	1831	1.097	2.146	1.514	39 (5)	28 (3.5)	–
22	Social care needs	1874	0.911	1.782	1.257	33 (4.3)	24 (3)	–
23	Other	11,666	0.494	0.494	0.682	58 (7.4)	80 (10.1)	–
All 23 PBCs		*78,398*				*784 (100)*	*784 (100)*	

a Without the negative sign.

TABLE 158 Number of deaths above LE in 2008/9/10, by PBC

PBC		2008 (1) < LE	2008 (2) > LE	2009 (3) < LE	2009 (4) > LE	2010 (5) < LE	2010 (6) > LE	(7) Annual deaths < LE	(8) Annual deaths > LE
1	Infectious diseases	3406	2586	3044	2190	2667	1894	3039	2223
2	Cancer	94,873	37,029	94,276	37,151	94,309	38,198	94,486	37,459
4	Endocrine	4033	2877	3834	2826	3816	2902	3894	2868
7	Neurological	9638	6859	9445	6939	9951	7480	9678	7093
10	Circulatory	80,894	76,292	76,048	73,342	74,035	73,719	76,992	74,451
11	Respiratory	32,083	35,180	29,912	33,304	29,691	33,176	30,562	33,887
13	Gastrointestinal	15,945	8259	15,361	8161	15,595	8372	15,633	8264
17	Genitourinary	4471	6667	4378	6900	4453	7166	4434	6911
18 + 19	Maternity and neonates	267	0	281	1	247	0	265	0

TABLE 159 Net YLL using LE for each PBC (2008)

PBC		(1) LE of males	(2) LE of females	Average 2006–8 Deaths (3) < LE	Average 2006–8 Deaths (4) > LE	(5) YLL	(6) YLG	(7) Net YLL
1	Infectious diseases	79.6	83.6	2919	2344	53,926	15,132	38,794
2	Cancer	83.0	84.7	100,487	31,459	1,456,255	134,089	1,322,166
4	Endocrine	81.0	84.7	3945	2818	65,800	15,983	49,817
7	Neurological	79.6	83.3	9112	7659	137,791	47,722	90,069
10	Circulatory	83.0	86.5	89,434	62,009	1,049,459	278,421	771,038
11	Respiratory	80.3	84.0	29,828	34,621	306,838	229,403	77,434
13	Gastrointestinal	80.6	84.5	15,612	8286	271,395	46,141	225,254
17	Genitourinary	83.5	85.6	5058	6287	49,036	32,528	16,508
18 + 19	Maternity and neonates	78.7	83.1	265	0	19,783	1	19,781

TABLE 160 Summary of cost per life-year threshold (2008)

PBC scenario	(1) 2006	(2) 2008
All big four programmes	£8080	£10,220
11 PBCs (with mortality)	£15,628	£23,360
All 23 PBCs (zero health effects for remaining 12 PBCs)	£57,497	£64,275
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	£17,663	£25,214

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

TABLE 161 Breakdown of the cost per life-year threshold (2008)

PBC		(1) Change in spend (£M)	Using LE of the PBC population		
			(2) Net YLL	(3) Change in Net YLL	(4) Cost per YLG (£)
2	Cancer	25	1,322,166	2131	11,931
10	Circulatory problems	43	771,038	6590	6544
11	Respiratory problems	26	77,434	913	28,528
13	Gastrointestinal problems	18	225,254	1401	12,983
All big four programmes					*10,220*
1	Infectious diseases	19	38,794	302	61,425
4	Endocrine problems	11	49,817	282	38,122
7	Neurological problems	34	90,069	368	92,282
17	Genitourinary problems	26	16,508	186	141,746
16	Trauma and injuries	44	N/A	0	N/A
18 + 19	Maternity and neonates	39	19,781	24	1,608,817
First 11 PBCs					*23,360*
3	Disorders of blood	23		979	23,360
5	Mental health disorders	198		8496	23,360
6	Learning disability	12		493	23,360
8	Problems of vision	22		924	23,360
9	Problems of hearing	10		416	23,360
12	Dental problems	32		1374	23,360
14	Skin	22		935	23,360
15	Musculoskeletal system	40		1726	23,360
20	Poisoning and adverse events	10		441	23,360
21	Healthy individuals	39		1682	23,360
22	Social care needs	33		1430	23,360
23	Other	58		0	N/A
All 23 PBCs					*25,214*

N/A, not applicable.
We have been unable to obtain a satisfactory outcome model for trauma and injuries and have assumed a zero outcome elasticity.

The estimates of net YLL imply a number of excess deaths required to generate them in each PBC. The implied excess deaths associated with net YLL are reported in *Table 162*.

The cost per excess death and the cost per PBC death averted are reported in *Table 163*, and a detailed breakdown of changes in spend and excess or total deaths across PBCs is shown in *Table 164*. The cost per PBC death averted is, of course, significantly lower than the cost per excess death as excess deaths are only a proportion of total deaths (see *Table 163*).

TABLE 162 Excess deaths implied by net YLL (2008)

PBC		(1) Net YLL	(2) YLL per observed death	(3) Excess deaths	(4) Total deaths	(5) % excess deaths
1	Infectious diseases	38,794	13.4	2934	5262	56
2	Cancer	1,322,166	14.1	93,917	131,945	71
4	Endocrine	49,817	13.7	3663	6762	54
7	Neurological	90,069	13.6	6642	16,771	40
10	Circulatory	771,038	10.5	74,217	151,443	49
11	Respiratory	77,434	9.2	8432	64,449	13
13	Gastrointestinal	225,254	15.2	15,049	23,897	63
17	Genitourinary	16,508	8.3	1978	11,345	17
18 + 19	Maternity and neonates	19,781	74.1	265	265	100

Excess deaths are calculated for each gender by dividing net YLL by the YLL per death [column (3) = column (1)/column(2)].

TABLE 163 Summary of the cost per death averted threshold (2008)

PBC scenario	2006–8		2008–10	
	(1) Cost per excess death averted (£)	(2) Cost per PBC death averted (£)	(3) Cost per excess death averted (£)	(4) Cost per PBC death averted (£)
All big four programmes	91,129	32,864	115,234	46,692
11 PBCs (with mortality)	177,691	64,774	265,784	105,872
All 23 PBCs (zero health effects for remaining 12 PBCs)	653,744	238,310	731,301	291,305
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	200,828	73,208	286,872	114,272

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

TABLE 164 Breakdown of the cost per death averted threshold (2008)

PBC		(1) Change in spend (£M)	PBC deaths			Excess deaths		
			(2) Total PBC deaths	(3) Change in PBC deaths	(4) Cost per PBC death averted (£)	(5) Excess deaths	(6) Change in excess deaths	(7) Cost per excess death averted (£)
2	Cancer	25	131,945	212.66	119,559	93,917	151.37	167,969
10	Circulatory problems	43	151,443	1294.40	33,316	74,217	634.34	67,983
11	Respiratory problems	26	64,449	759.74	34,276	8432	99.40	261,992
13	Gastrointestinal problems	18	23,897	148.64	122,379	15,049	93.60	194,332
All big four programmes					*46,692*	*0*		*115,234*
1	Infectious diseases	19	5262	40.97	452,858	2934	22.84	812,249
4	Endocrine problems	11	6762	38.29	280,856	3663	20.74	518,533
7	Neurological problems	34	16,771	68.54	495,603	6642	27.14	1,251,391
17	Genitourinary problems	26	11,345	127.71	206,253	1978	22.27	1,182,744
16	Trauma and injuries	44	N/A	0	N/A	N/A	0	N/A
18 + 19	Maternity and neonates	39	265	0.32	120,090,566	265	0.32	120,090,566
First 11 PBCs					*105,872*			*265,784*
3	Disorders of blood	23		215.92	105,872		86.01	265,784
5	Mental health disorders	198		1874.69	105,872		746.76	265,784
6	Learning disability	12		108.86	105,872		43.36	265,784
8	Problems of vision	22		203.97	105,872		81.25	265,784
9	Problems of hearing	10		91.76	105,872		36.55	265,784
12	Dental problems	32		303.11	105,872		120.74	265,784
14	Skin	22		206.34	105,872		82.19	265,784
15	Musculoskeletal system	40		380.77	105,872		151.68	265,784
20	Poisoning and adverse events	10		97.40	105,872		38.80	265,784
21	Healthy individuals	39		371.11	105,872		147.83	265,784
22	Social care needs	33		315.43	105,872		125.65	265,784
23	Other	58		0	N/A		0	N/A
All 23 PBCs					*114,272*			*286,872*

N/A, not applicable.

The number of YLGs associated with each excess death averted are reported for each PBC in *Table 165* [see column (1)] and range from 74.6 years for PBC 18 + 19 to 8.3 years for PBC 17. On average, across all 11 PBCs each excess death averted is associated with 11.4 YLGs. The life-years associated with each observed death are reported for each PBC in *Table 165*, column (2) and range from 74.6 years in PBC 18 + 19 to 1.2 for PBC 11. On average, across all 11 PBCs each PBC death averted is associated with 4.5 YLGs.

Summary of cost per life-year estimates

The cost per life-year threshold in lines (1)–(4) in *Table 166* are regarded as the central or best estimates given the evidence available and the credibility of the alternative assumption that could be made. As explained in the *Introduction*, these are based on the conservative assumption that any health effects of changes in expenditure are restricted to 1 year, which, to some extent, may be offset by the more optimistic assumption that any death averted returns the individual to the mortality risk faced by the general population, matched for age and gender. See *How uncertain are the estimates?* for guidance in the interpretation of the upper and lower bound estimates.

Adjusting life-years for quality-of-life

The central or best estimates of the cost per life-year threshold, presented in *Table 166* [see lines (2) and (4)] take no account of the health-related QoL in which years of life, expected to be gained or lost through changes in expenditure, are likely to be lived. In this section we examine the ways in which the life-years can be adjusted for quality, taking account of information that is available about (i) how QoL differs by age and gender, and (ii) how the quality-of-life-years associated with mortality changes might be affected by the types of diseases that make up each PBC.

TABLE 165 Implied YLL per death averted for each PBC (2008)

PBC		(1) Implied YLL per excess death averted	(2) Implied YLL per PBC death averted
2	Cancer	14.1	10.0
10	Circulatory problems	10.4	5.1
11	Respiratory problems	9.2	1.2
13	Gastrointestinal problems	15.0	9.4
All big four programmes		*11.3*	*4.6*
1	Infectious diseases	13.2	7.4
4	Endocrine problems	13.6	7.4
7	Neurological problems	13.6	5.4
17	Genitourinary problems	8.3	1.5
16	Trauma and injuries	N/A	N/A
18 + 19	Maternity and neonates	74.6	74.6
First 11 PBCs		*11.4*	*4.5*

N/A, not applicable.

TABLE 166 Summary of the cost per life-year threshold with upper and lower bounds (2008)

PBC grouping	(1) 2006–8	(2) 2008–10
Best estimate		
Effect of expenditure on mortality	1 year	1 year
YLL per PBC death averted	~4.1[a]	~4.5[a]
(1) All big four programmes	£8080	£10,220
(2) 11 PBCs (with mortality)	£15,628	£23,360
(3) All 23 PBCs (zero health effects for remaining 12 PBCs)	£57,497	£64,275
(4) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[b]	£17,663	£25,214
Lower bound		
Effect of expenditure on mortality	Remainder of disease	Remainder of disease
YLL per PBC death averted	~4.1[a]	~4.5[a]
(5) All big four programmes	£3846	£5083
(6) 11 PBCs (with mortality)	£6106	£8579
(7) All 23 PBCs (zero health effects for remaining 12 PBCs)	£22,463	£23,605
(8) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[b]	£6901	£9260
Upper bound		
Effect of expenditure on mortality	1 year	1 year
YLL per PBC death averted	2	2
(9) All big four programmes	£16,432	£23,346
(10) 11 PBCs (with mortality)	£32,387	£52,936
(11) All 23 PBCs (zero health effects for remaining 12 PBCs)	£119,155	£145,653
(12) All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[b]	£36,604	£57,136

a See *Table 165*.
b In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal.

Quality of life based on the general population

Quality-of-life norms (see *Figure 49*) can be applied to the YLL associated with all observed deaths in each PBC, taking account of gender and age at death. The results are reported in column (4)–(6) of *Table 167*.

The implications of the quality adjustment to a cost per QALY threshold that only accounts for the direct health effects of mortality are summarised in *Table 168*, and detailed in *Table 169*.

Table 170 depicts the judgements over life-years, QoL weights and total QALYs implicit in calculations of the threshold cost per QALY in *Table 166*.

TABLE 167 Net YLL adjusted for QoL 'norms' (2008)

		Unadjusted life-years			QALYs		
PBC		(1) YLL	(2) YLG	(3) Net YLL	(4) YLG	(5) YLL	(6) Net YLG
1	Infectious diseases	53,926	15,132	38,794	43,703	10,187	33,516
2	Cancer	1,456,255	134,089	1,322,166	1,129,191	89,231	1,039,960
4	Endocrine	65,800	15,983	49,817	52,465	10,598	41,867
7	Neurological	137,791	47,722	90,069	110,532	32,262	78,270
10	Circulatory	1,049,459	278,421	771,038	807,893	183,796	624,097
11	Respiratory	306,838	229,403	77,434	237,981	154,300	83,680
13	Gastrointestinal	271,395	46,141	225,254	214,756	30,811	183,945
17	Genitourinary	49,036	32,528	16,508	37,178	21,190	15,989
18 + 19	Maternity and neonates	19,783	1	19,781	17,176	1	17,175

TABLE 168 Summary of cost per QALY threshold based on population norms and mortality effects (2008)

	2006–8		2008–10	
PBC scenario	(1) Cost per life-year threshold (£)	(2) Cost per QALY threshold (£) population norms	(3) Cost per life-year threshold (£)	(4) Cost per QALY threshold (£) population norms
All big four programmes	8080	9631	10,220	12,338
11 PBCs	15,628	18,622	23,360	28,045
All 23 PBCs	17,663	21,047	25,214	30,270

TABLE 169 A breakdown of the cost per QALY threshold based on population norms (2008)

PBC		(1) Change in spend (£M)	YLL using LE of PBC	
			(2) Change in QALY	(3) Cost per QALY gained (£)
2	Cancer	25	1676	15,169
10	Circulatory problems	43	5334	8084
11	Respiratory problems	26	986	26,399
13	Gastrointestinal problems	18	1144	15,899
All big four programmes				*12,338*
1	Infectious diseases	19	261	71,098
4	Endocrine problems	11	237	45,361
7	Neurological problems	34	320	106,193
17	Genitourinary problems	26	180	146,347
16	Trauma and injuries	44	0	N/A
18 + 19	Maternity and neonates	39	21	1,852,926
First 11 PBCs				*28,045*
3	Disorders of blood	23	815	28,045
5	Mental health disorders	198	7077	28,045
6	Learning disability	12	411	28,045
8	Problems of vision	22	770	28,045
9	Problems of hearing	10	346	28,045
12	Dental problems	32	1144	28,045
14	Skin	22	779	28,045
15	Musculoskeletal system	40	1437	28,045
20	Poisoning and adverse effects	10	368	28,045
21	Healthy individuals	39	1401	28,045
22	Social care needs	33	1191	28,045
23	Other	58	0	N/A
All 23 PBCs				*30,270*

N/A, not applicable.

TABLE 170 Implied YLL per excess death averted and implied QoL score per YLL gained, for each PBC (2008)

PBC		(1) Implied YLL per excess death averted	(2) Implied YLL per PBC death averted	(3) Implied QALYs gained per excess death averted	(4) Implied QALYs gained per PBC death averted
2	Cancer	14.08	10.02	11.07	7.88
10	Circulatory	10.39	5.09	8.41	4.12
11	Respiratory	9.18	1.20	9.92	1.30
13	Gastrointestinal	14.97	9.43	12.22	7.70
All big four programmes		*11.28*	*4.57*	*9.34*	*3.78*
1	Infectious diseases	13.22	7.37	11.42	6.37
4	Endocrine	13.60	7.37	11.43	6.19
7	Neurological	13.56	5.37	11.78	4.67
17	Genitourinary	8.34	1.46	8.08	1.41
16	Trauma and injuries	N/A	N/A	N/A	N/A
18 + 19	Maternity and neonates	74.65	74.65	64.81	64.81
First 11 PBCs		*11.38*	*4.53*	*9.48*	*3.78*

N/A, not applicable.

Adjusting age-related quality-of-life for disease decrements

By using age-related QoL disease decrements (exemplified in *Figure 50*) YLL can be adjusted for QoL of disease. The results are reported in columns (4)–(6) of *Table 171*.

The implications of the quality adjustment to a cost per QALY threshold that only accounts for the direct health effects of mortality are summarised in *Table 172*, and detailed in *Table 173*.

Table 174 depicts the judgements over life-years, QoL weights and total QALYs implicit in calculations of the threshold cost per QALY in *Table 172*.

TABLE 171 Net YLL adjusted for disease and age-related QoL (2008)

		Unadjusted life-years			QALYs		
PBC		(1) YLL	(2) YLG	(3) Net YLL	(4) YLG	(5) YLL	(6) Net YLG
1	Infectious diseases	53,926	15,132	38,794	34,108	7524	26,584
2	Cancer	1,456,255	134,089	1,322,166	943,650	72,197	871,452
4	Endocrine	65,800	15,983	49,817	43,063	8334	34,729
7	Neurological	137,791	47,722	90,069	69,520	18,084	51,436
10	Circulatory	1,049,459	278,421	771,038	625,150	135,622	489,527
11	Respiratory	306,838	229,403	77,434	173,953	106,200	67,754
13	Gastrointestinal	271,395	46,141	225,254	162,441	22,060	140,380
17	Genitourinary	49,036	32,528	16,508	30,770	16,949	13,820
18 + 19	Maternity and neonates	19,783	1	19,781	16,100	1	16,099

TABLE 172 Summary of cost per QALY threshold based on disease- and age-related QoL and mortality effects (2008)

PBC scenario	2006		2008	
	(1) Cost per life-year threshold (£)	(2) Cost per QALY threshold (£) disease-related disutility	(3) Cost per life-year threshold (£)	(4) Cost per QALY threshold (£) disease-related disutility
All big four programmes	8080	12,109	10,220	15,534
11 PBCs (with mortality)	15,628	23,395	23,360	35,397
All 23 PBCs (zero health effects for remaining 12 PBCs)	57,497	86,072	64,275	97,395
All 23 PBCs (non-zero health effects for remaining 12 PBCs, except GMS)[a]	17,663	26,441	25,214	38,206

a In PBCs without a mortality signal, health effects were estimated by valuing changes in expenditure at the same rate as observed in PBCs for which there was a mortality signal, except GMS.

TABLE 173 A breakdown of the cost per QALY threshold based on disease- and age-related QoL and mortality effects (2008)

PBC		(1) Change in spend (£M)	YLL using LE of PBC	
			(2) Change in QALY	(3) Cost per QALY gained (£)
2	Cancer	25	1405	18,102
10	Circulatory problems	43	4184	10,307
11	Respiratory problems	26	799	32,604
13	Gastrointestinal problems	18	873	20,833
All big four programmes				*15,534*
1	Infectious diseases	19	207	89,638
4	Endocrine problems	11	197	54,685
7	Neurological problems	34	210	161,594
17	Genitourinary problems	26	156	169,315
16	Trauma and injuries	44	0	N/A
18 + 19	Maternity and neonates	39	20	1,976,769
First 11 PBCs				*35,397*
3	Disorders of blood	23	646	35,397
5	Mental health disorders	198	5607	35,397
6	Learning disability	12	326	35,397
8	Problems of vision	22	610	35,397
9	Problems of hearing	10	274	35,397
12	Dental problems	32	907	35,397
14	Skin	22	617	35,397
15	Musculoskeletal system	40	1139	35,397
20	Poisoning and adverse effects	10	291	35,397
21	Healthy individuals	39	1110	35,397
22	Social care needs	33	943	35,397
23	Other	58	0	N/A
All 23 PBCs				*38,206*

N/A, not applicable.

TABLE 174 Implied YLL per excess death averted and implied QoL score per YLL gained, for each PBC (2008)

PBC		(1) Implied YLL per excess death averted	(2) Implied YLL per PBC death averted	(3) Implied QALYs gained per excess death averted	(4) Implied QALYs gained per PBC death averted
2	Cancer	14.08	10.02	9.28	6.60
10	Circulatory	10.39	5.09	6.60	3.23
11	Respiratory	9.18	1.20	8.04	1.05
13	Gastrointestinal	14.97	9.43	9.33	5.87
All big four programmes		*11.28*	*1.80*	*7.42*	*3.01*
1	Infectious diseases	13.22	7.37	9.06	5.05
4	Endocrine	13.60	7.37	9.48	5.14
7	Neurological	13.56	5.37	7.74	3.07
17	Genitourinary	8.34	1.46	6.99	1.22
16	Trauma and injuries	N/A	N/A	N/A	N/A
18 + 19	Maternity and neonates	74.65	74.65	60.75	60.75
First 11 PBCs		*11.38*	*4.53*	*6.77*	*2.99*

N/A, not applicable.

Summary of the cost per quality-adjusted life-year threshold based only on mortality effects

The analysis to this point is summarised in *Table 175*. The three estimates of a cost per QALY threshold are based on assuming that each YLG is either lived in full health [see *Table 175*, column (1)]; lived in a QoL that reflects age and gender norms of the general population [see *Table 175*, column (2)]; or lived in a QoL that reflects the original disease state [see *Table 175*, column (3)].

Including quality-of-life effects during disease

In this section we explore how estimates of effects of expenditure that can be observed (i.e. on mortality) can be used to infer the likely effects on what cannot be directly observed (QoL), rather than making extreme assumptions that are not credible (e.g. assuming that changes in expenditure will have no effects on QoL outcomes). In *Using estimates of the quality-adjusted life-year burden of disease*, we described the use of ratios of QALYs lost to life-years lost due to disease and explored how the use of the QALY burden of disease is preferable to inform estimates of the threshold. Here we only present the results for the QALY burden of disease approach.

TABLE 175 Summary of QALY threshold estimates based only on mortality effects (2008)

PBC scenario	(1) QoL score = 1	(2) QoL norm	(3) QoL diseased
Best estimate			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted[a]	~4.5	~4.5	~4.5
QALYs per death averted[a]	~4.5	~3.8	~3.0
(1) All big four programmes	£10,220	£12,338	£15,534
(2) 11 PBCs	£23,360	£28,045	£35,397
(3) All 23 PBCs	£25,214	£30,270	£38,206
Lower bound			
Effect of expenditure on mortality	Remainder of disease	Remainder of disease	Remainder of disease
YLL per death averted[a]	~4.5	~4.5	~4.5
QALYs per death averted[a]	~4.5	~3.8	~3.0
(4) All big four programmes	£5083	£5811	£7305
(5) 11 PBCs	£8579	£9861	£12,720
(6) All 23 PBCs	£9260	£10,644	£13,729
Upper bound			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted[a]	2	2	2
QALYs per death averted[a]	~2	~1.8	~1.4
(7) All big four programmes	£23,346	£26,138	£32,797
(8) 11 PBCs	£52,936	£59,151	£74,183
(9) All 23 PBCs	£57,136	£63,844	£80,069

a See *Table 174*.

In *Table 176*, deaths and YLL from ONS (2008–10 mortality data) are compared with those from GBD. The factors used to adjust GBD information are reported in columns (4) and (7).

The threshold cost per QALY based on burden associated with 1 year of disease derived from GBD are summarised in *Table 177*, and detailed in *Table 178*.

Summary of the cost per quality-adjusted life-year threshold

The results of the three sequential steps of analysis are summarised in *Table 179*, for this year of analysis. They include (i) the cost per life-year [see *Table 179*, column (1)] based on the methods of analysis outlined in *From mortality to life-years*; (ii) the cost per life-year adjusted for QoL [see *Table 179*, column (2)] based on the methods of analysis outlined in *Adjusting life-years for quality-of-life*; and (iii) the cost per QALY [see *Table 179*, column (3)] based on the methods of analysis outlined in *Including quality-of-life effects during disease*. These estimates, in *Table 179*, column (3), take account of the likely effects of changes in expenditure on QoL during disease as well as the effects associated with mortality and life-years; making best use of available information, while the assumptions required appear more reasonable than the other alternatives available. For this reason these estimates remain our central or best estimates for all the waves of expenditure and mortality data.

TABLE 176 Comparing deaths and YLL from ONS and GBD (2008)

PBC			Deaths			YLL		
		(1) Excess deaths ONS	(2) All deaths ONS	(3) All deaths GBD	(4) Adjustment factor (deaths)	(5) Net estimates ONS	(6) Total YLLGBD	(7) Adjustment factor (YLL)
1	Infectious diseases	2934	5262	1408	3.737	38,794	25,142	1.543
2	Cancer	93,917	131,946	140,124	0.942	1,322,166	1,932,637	0.684
4	Endocrine	3663	6762	7509	0.901	49,817	95,401	0.522
7	Neurological	6642	16,771	12,854	1.305	90,069	164,796	0.547
10	Circulatory	74,217	151,443	178,454	0.849	771,038	1,750,608	0.440
11	Respiratory	8432	64,449	67,441	0.956	77,434	594,529	0.130
13	Gastrointestinal	15,049	23,897	28,329	0.844	225,254	396,829	0.568
17	Genitourinary	1978	11,345	8606	1.318	16,508	77,338	0.213
18 + 19	Maternity and neonates	265	265	2211	0.120	19,781	149,868	0.132
Total		*207,097*	*412,140*	*446,936*	*0.92*	*2,610,861*	*5,187,148*	*0.500*

TABLE 177 Summary of the cost per QALY threshold (2008)

PBC scenario	(1) 2006	(2) 2008
All big four programmes	£3036	£4872
11 PBCs (with mortality)	£5128	£8308
All 23 PBCs	£10,187	£12,936

TABLE 178 Breakdown of the cost per QALY threshold (2008)

PBC		(1) Change in spend (£M)	QALY burden (HODaR and MEPS) (2) Change in QALY	(3) Cost per QALY gained (£)
2	Cancer	35	2064	16997
10	Circulatory problems	59	8453	7038
11	Respiratory problems	36	17,981	1998
13	Gastrointestinal problems	25	3441	7293
All big four programmes				*4872*
1	Infectious diseases	26	1229	20,829
4	Endocrine problems	15	4749	3124
7	Neurological problems	47	8551	5480
17	Genitourinary problems	36	829	43,813
16	Trauma and injuries	60	0	N/A
18 + 19	Maternity and neonates	54	18	2,969,208
First 11 PBCs				*8308*
3	Disorders of blood	16	1712	9419
5	Mental health disorders	140	7469	18,744
6	Learning disability	8	54	149,883
8	Problems of vision	15	333	45,788
9	Problems of hearing	7	1098	6239
12	Dental problems	23	533	42,472
14	Skin	15	152	101,042
15	Musculoskeletal system	28	1819	15,628
20	Poisoning and adverse effects	7	64	113,546
21	Healthy individuals	28	53	526,771
22	Social care needs	24		N/A
23	Other	80		N/A
All 23 PBCs				*12,936*

N/A, not applicable.

TABLE 179 Summary of cost per QALY threshold estimates (2008)

PBC scenario	(1) *Chapter 4, From mortality to life-years* analysis	(2) *Chapter 4, Adjusting life-years for quality of life* analysis	(3) *Chapter 4, Including quality-of-life effects during disease* analysis
QoL associated with life extension	1	Norm	
QoL during disease	0	0	Based on burden
Best estimate			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	~4.5	~4.5	~4.5
QALYs per death averted	~4.5	~3.8	~15.0
(1) All big four programmes	£10,220	£12,338	£4872
(2) 11 PBCs (with mortality)	£23,360	£28,045	£8308
(3) All 23 PBCs	£25,214	£30,270	**£12,936**
Lower bound			
Effect of expenditure on mortality	Remainder of disease duration	Remainder of disease duration	Remainder of disease duration
YLL per death averted	~4.5	~4.5	~4.5
QALYs per death averted	~4.5	~3.8	~15.0
(4) All big four programmes	£5083	£5811	£1194
(5) 11 PBCs (with mortality)	£8579	£9861	£1175
(6) All 23 PBCs	£9260	£10,644	**£2018**
Upper bound			
Effect of expenditure on mortality	1 year	1 year	1 year
YLL per death averted	2	2	2
QALYs per death averted	~2	~1.4	~6.6
(7) All big four programmes	£23,346	£26,138	£11,040
(8) 11 PBCs (with mortality)	£52,936	£59,151	£18,827
(9) All 23 PBCs	£57,136	£63,844	**£29,314**

Which programme budget categories matter most?

The estimate of £8308 per QALY [see *Table 179*, line (2)] is restricted to the effects of changes in expenditure in the 11 PBCs where outcome elasticities can be estimated. However, these PBCs only account for a proportion of a change in overall expenditure (approximately 50%, *Table 180*). As was explained in *Including quality-of-life effects during disease* the QALY threshold of £12,936 [see *Table 179*, column (3), line (3)] uses the estimated proportionate effects of expenditure on the QALY burden of disease in the 11 PBCs as a surrogate for proportionate effects in the others (i.e. assuming that the effects that can be observed will be similar to those that cannot), and represents our central or best estimate. As in previous sections, no health effects are assigned to PBC 23 or 22 (GMS and social care) on the basis that any health effects of this expenditure would be recorded in the other PBCs. Although this estimate of £12,936 reflects changes in undiscounted QALYs associated with changes in expenditure, discounting the QALY effects only increases the cost per QALY threshold to £13,141 (*Table 181*). The effects of discounting are modest because (i) the health effects of a change in expenditure are restricted to 1 year (where no discounting is necessary); (ii) most of the total QALY effects occur in that year; (iii) it is only some of the life-year effects (adjusted for quality) of a change in mortality in that year that occur in future years that need to be discounted; and (iv) these need to be discounted only over 4.5 years on average.

TABLE 180 Impact of each PBC on the overall cost per QALY threshold (2008)

PBC		(1) % share of change in overall expenditure	(2) % share of total health effects (QALY)	(3) Elasticity of the threshold[a]	(4) PBC cost per QALY (£)
2	Cancer	4.47	3.41	0.34	16,997
10	Circulatory	7.59	13.95	1.40	7038
11	Respiratory	4.58	29.67	2.97	1998
13	Gastrointestinal	3.20	5.68	0.57	7293
1	Infectious diseases	3.27	2.03	0.20	20,829
4	Endocrine	1.89	7.84	0.78	3124
7	Neurological	5.98	14.11	1.41	5480
17	Genitourinary	4.64	1.37	0.14	43,813
16	Trauma and injuries	7.70	0.00	0.00	N/A
18 + 19	Maternity and neonates	6.83	0.03	< 0.01	2,969,208
3	Disorders of blood	2.06	2.82	0.28	9419
5	Mental health	17.86	12.32	1.23	18,744
6	Learning disability	1.04	0.09	0.01	149,883
8	Problems of vision	1.94	0.55	0.05	45,788
9	Problems of hearing	0.87	1.81	0.18	6239
12	Dental problems	2.89	0.88	0.09	42,472
14	Skin	1.97	0.25	0.03	101,042
15	Musculoskeletal	3.63	3.00	0.30	15,628
20	Poisoning and adverse events	0.93	0.11	0.01	113,546
21	Healthy individuals	3.53	0.09	0.01	526,771
22	Social care needs	3.00	0.00	0.00	N/A
23	Other	10.14	0.00	0.00	N/A

N/A, not applicable.
a Calculated using the effect on the threshold of a 10% increase (or decrease) in QALY change of the PBC.

TABLE 181 Summary of QALY threshold, discounted (2008)

PBC scenario	2008–10 (£) discounted, best estimate
(1) All big four programmes	4998
(2) 11 PBCs	8467
(3) All 23 PBCs	13,141

Only quality adjusted net YLL were discounted, and thus QALYs associated with gains in QoL during disease were not. The discounting factor has been calculated by applying a 3.5% discount rate to each year of life lost in the PBCs – the estimate of YLL used was the implied YLL per death averted in each PBC [in column (2) of *Table 165*]. This discounting factor was applied to net YLL before applying the outcome elasticity to calculate YLL averted.

The upper and lower bounds for the cost per QALY thresholds in column (3) are based on making the necessary assumptions about duration of health effects and how long a death might be averted optimistic (providing the lower bound for the threshold) or conservative (an upper bound for the threshold). The lower bound [see *Table 179*, lines (4)–(6)] is based on assuming that health effects are not restricted to 1 year but apply to the whole of the remaining disease duration of the population at risk in PBCs during 1 year. Although this combines optimistic assumptions, it is possible that at least some part of a change in expenditure may prevent disease so will have an impact on populations that are incident to PBCs in the future. Such effects are not captured in any of the estimates presented in this report so all are conservative in this respect. The upper bound [see *Table 179*, lines (7)–(9)] is based on the combination of assuming that health effects are restricted to 1 year for the population currently at risk and that any death averted is only averted for 2 years (see *Summary of cost per life-year estimates*).

The estimated QALY effects associated with each PBC can be decomposed into that part due to life-year effects adjusted for quality and that part associated with effects on quality during disease (*Table 182*). Those PBCs for which mortality is the major concern have a much greater share of total QALY effects associated with avoidance of premature death (e.g. PBCs 2 and 10) compared with those where QoL is the major concern (e.g. PBC 7).

TABLE 182 Decomposing estimated QALY effects by PBC (2008)

PBC		(1) QALY change (total)	(2) QALY change (death)	% QALY gained	
				(3) For premature death	(4) For disability while alive
2	Cancer	2064	1912	93	7
10	Circulatory	8453	5778	68	32
11	Respiratory	17,981	789	4	96
13	Gastrointestinal	3441	1268	3	63
1	Infectious diseases	1229	282	23	77
4	Endocrine	4749	254	5	95
7	Neurological	8551	335	4	96
17	Genitourinary	829	162	20	80
16	Trauma and injuries	0	0	N/A	N/A
18 + 19	Maternity and neonates	18	12	69	31
3	Disorders of blood	1712	88	5	95
5	Mental health	7469	652	9	91
6	Learning disability	54	11	20	80
8	Problems of vision	333	13	4	96
9	Problems of hearing	1098	8	1	99
12	Dental problems	533	1	0	100
14	Skin	152	56	37	63
15	Musculoskeletal	1819	90	5	95
20	Poisoning and adverse events	64	10	16	84
21	Healthy individuals	53	8	16	84
22	Social care needs	0	0	N/A	N/A
23	Other	0	0	N/A	N/A

N/A, not applicable.

How uncertain are the estimates?

In the earlier section *How uncertain are the estimates?* (pp. 432), the impact of uncertainty over the spend and outcome elasticities on estimates of the cost per QALY threshold has been illustrated and interpreted in detail using expenditure data from 2006/7. Here we repeat this analysis using expenditure data from 2008/9 and mortality data from 2008–10 (*Table 183*). *Figure 53* shows the histogram of threshold values from the Monte Carlo simulation (where each random sample from the simulation represents one possible realisation of the overall threshold), and *Figure 54* shows the cumulative probability density function for a cost per QALY threshold based on the 11 PBCs with estimated outcome elasticities and for all 23 PBCs.

TABLE 183 Uncertainty over the QALY threshold (2008)

Scenario	(1) 11 PBCs	(2) All 23 PBCs
Best estimate (deterministic)	£8308	£12,936
Mean estimate (from the simulations)	£8330	£13,050
Threshold value at the probability of (from the simulations)		
2.5%	£5176	£8141
5.0%	£5438	£8760
50.0%	£8346	£13,084
95.0%	£17,452	£25,505
97.5%	£21,693	£32,173
Probability (from the simulations) of the threshold being smaller than		
£5000 per QALY	2%	0%
£6000 per QALY	10%	0%
£7000 per QALY	25%	0%
£8000 per QALY	45%	2%
£9000 per QALY	59%	6%
£10,000 per QALY	71%	13%
£15,000 per QALY	93%	68%
£20,000 per QALY	97%	89%
£25,000 per QALY	98%	95%
£30,000 per QALY	99%	97%
£35,000 per QALY	99%	98%
£40,000 per QALY	99%	99%
£45,000 per QALY	99%	99%
£50,000 per QALY	99%	99%

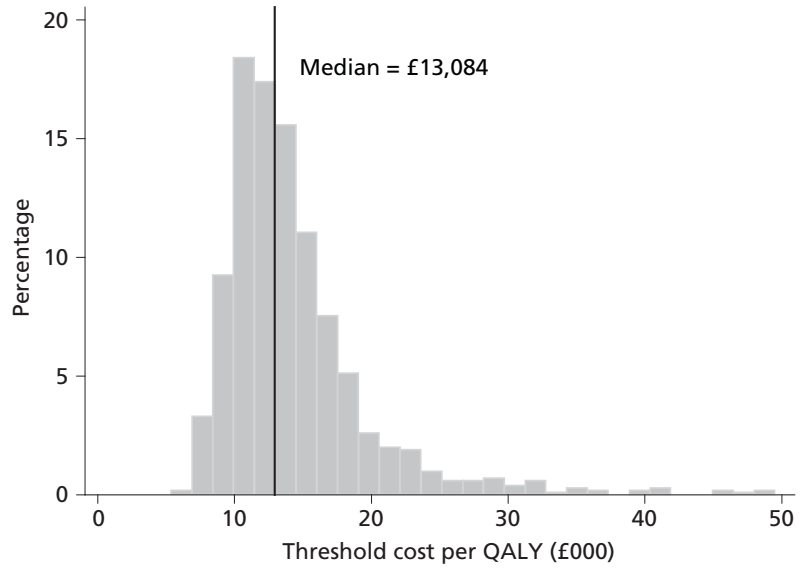


FIGURE 53 Histogram of simulation of undiscounted threshold (all 23 PBCs) (2008).

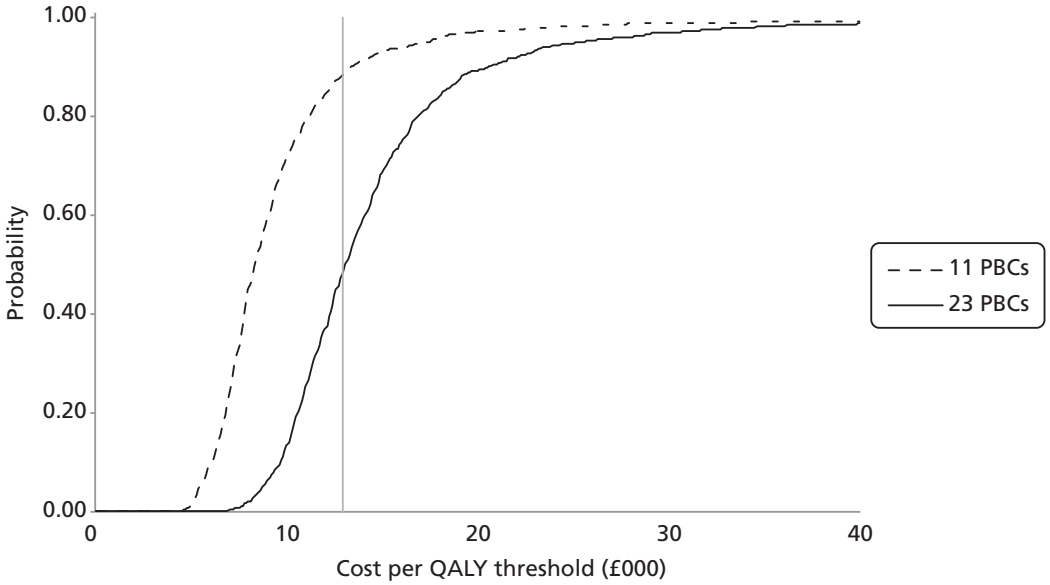


FIGURE 54 Cumulative probability density function for the cost per QALY threshold (2008).

Re-estimating the cost per quality-adjusted life-year threshold using 2007 expenditure data

The same methods of analysis were applied to the econometric analysis of the 2007/8 expenditure and 2007–9 mortality data (see *Analysis of programme budgeting expenditure for 2007/8 and mortality data for 2007/8/9* in *Appendix 2*). Given the detailed reporting of the methods and interpretation of the analyses for other expenditure years (see *Analysis of 2006/7 expenditure and 2006–8 mortality data* and *Re-estimating the cost per quality-adjusted life-year threshold using 2008 expenditure data*), we will here only present the necessary tables of results (*Tables 184–192*).

TABLE 184 Outcome and spend elasticities (2007)

PBC		(1) Total spend 2007/8 (£)	Spend elasticities		(4) Outcome elasticities[a]
			(2) Unadjusted	(3) Adjusted	
2	Cancer	4573	0.890	0.890	0.365
10	Circulatory problems	6325	0.293	0.293	1.277
11	Respiratory problems	3431	0.536	0.536	2.205
13	Gastrointestinal problems	3805	0.622	0.622	1.328
All big four programmes		*18,134*			
1	Infectious diseases	1119	1.436	1.436	0.548
4	Endocrine problems	1997	0.264	0.264	0.566
7	Neurological problems	3165	1.035	1.035	0.339
17	Genitourinary problems	3439	1.004	1.004	1.855
16	Trauma and injuries	2918	1.686	1.686	0.369[b]
18 + 19	Maternity and neonates	3662	0.514	0.514	0.110
First 11 PBCs		*34,434*			
3	Disorders of blood	986	1.830	2.879	–
5	Mental health disorders	9171	1.145	1.801	–
6	Learning disability	2748	0.440	0.692	–
8	Vision	1556	1.170	1.841	–
9	Hearing	409	1.029	1.619	–
12	Dental problems	3014	0.424	0.667	–
14	Problems of the skin	1542	0.428	0.673	–
15	Musculoskeletal system	3848	0.806	1.268	–
20	Poisoning and adverse events	803	0.668	1.051	–
21	Healthy individuals	1594	0.986	1.551	–
22	Social care needs	1789	1.852	2.913	–
23	Other	11,763	0.563	0.563	–
All 23 PBCs		*73,656*			

a Without the negative sign.
b Estimated 0.369 but not used in the threshold calculations for consistency with other years of analysis.

TABLE 185 Number of deaths above LE in 2007/8/9, by PBC

PBC		2007		2008		2009		Annual deaths < LE	Annual deaths > LE
		< LE	> LE	< LE	> LE	< LE	> LE		
1	Infectious diseases	3906	3731	3404	2588	3042	2192	3451	2837
2	Cancer	95,385	35,401	94,814	37,088	94,218	37,209	94,806	36,566
4	Endocrine	3970	2747	4031	2879	3832	2828	3944	2818
7	Neurological	8852	6494	9632	6865	9439	6945	9308	6768
10	Circulatory	80,687	78,404	80,834	76,352	75,993	73,397	79,172	76,051
11	Respiratory	29,571	35,029	32,059	35,204	29,890	33,326	30,507	34,520
13	Gastrointestinal	15,667	8367	15,937	8267	15,354	8168	15,653	8267
17	Genitourinary	4077	6553	4468	6670	4375	6903	4307	6709
18 + 19	Maternity and neonates	216	0	267	0	281	1	255	0

TABLE 186 Net YLL using LE of the PBC (2007)

PBC		LE of males (years)	LE of females (years)	Average 2007–9 Deaths				
				< LE	> LE	YLL	YLG	Net YLL
1	Infectious diseases	79.6	83.6	3280	3008	57,715	19,085	38,629
2	Cancer	83.0	84.7	100,810	30,561	1,464,726	129,810	1,334,916
4	Endocrine	81.0	84.7	4004	2759	66,575	15,386	51,189
7	Neurological	79.6	83.3	8719	7357	135,760	44,925	90,835
10	Circulatory	83.0	86.5	92,729	62,494	1,069,632	276,368	793,264
11	Respiratory	80.3	84.0	29,668	35,359	304,168	230,245	73,922
13	Gastrointestinal	80.6	84.5	15,640	8280	271,092	45,500	225,593
17	Genitourinary	83.5	85.6	5008	6007	47,656	30,931	16,725
18 + 19	Maternity and neonates	78.7	83.1	255	0	18,844	1	18,843

TABLE 187 Comparing deaths and YLL from ONS and GBD (2007)

PBC		Excess deaths ONS	Deaths			YLL		
			All deaths ONS	All deaths GBD	Adjustment factor (deaths)	Net estimates ONS	Total YLL GBD	Adjustment factor (YLL)
1	Infectious diseases	2925	6288	1408	4.47	38,629	25,142	1.54
2	Cancer	94,827	131,372	140,124	0.94	1,334,916	1,932,637	0.69
4	Endocrine	3765	6762	7509	0.90	51,189	95,401	0.54
7	Neurological	6692	16,076	12,854	1.25	90,835	164,796	0.55
10	Circulatory	76,322	155,223	178,454	0.87	793,264	1,750,608	0.45
11	Respiratory	8034	65,027	67,441	0.96	73,922	594,529	0.12
13	Gastrointestinal	15,064	23,920	28,329	0.84	225,593	396,829	0.57
17	Genitourinary	2005	11,016	8606	1.28	16,725	77,338	0.22
18 + 19	Maternity and neonates	255	255	2211	0.12	18,843	149,868	0.13
Total		*209,890*	*415,939*	*446,936*	*0.93*	*2,643,916*	*5,187,148*	*0.51*

TABLE 188 Summary of the cost per QALY threshold (2007)

PBC scenario	(1) 2006	(2) 2007	(3) 2008
All big four programmes	£3036	**£4549**	£4872
11 PBCs (with mortality)	£5128	**£8513**	£8308
All 23 PBCs	£10,187	**£13,554**	£12,936

TABLE 189 Breakdown of the cost per QALY threshold (2007)

PBC		(1) Change in spend (£M)	QALY burden (HODaR and MEPS) (2) Change in QALY	QALY burden (HODaR and MEPS) (3) Cost per QALY gained (£)
2	Cancer	51	3820	13,384
10	Circulatory problems	23	3462	6724
11	Respiratory problems	23	16,522	1398
13	Gastrointestinal problems	30	4166	7137
All big four programmes				*4549*
1	Infectious diseases	20	1300	15,530
4	Endocrine problems	7	1143	5796
7	Neurological problems	41	6421	6409
17	Genitourinary problems	43	1224	35,449
16	Trauma and injuries	62		
18 + 19	Maternity and neonates	24	7	3,250,386
First 11 PBCs				*8513*
3	Disorders of blood	23	2695	8407
5	Mental health disorders	132	8316	15,863
6	Learning disability	15	117	129,512
8	Problems of vision	23	600	38,140
9	Problems of hearing	5	956	5534
12	Dental problems	16	444	36,177
14	Skin	8	98	84,977
15	Musculoskeletal system	39	2926	13,319
20	Poisoning and adverse effects	7	77	87,852
21	Healthy individuals	20	48	414,420
22	Social care needs	42		N/A
23	Other	83		N/A
All 23 PBCs				*13,554*

N/A, not applicable.

TABLE 190 Decomposing estimated QALY effects by PBC (2007)

PBC		(1) QALY change (total)	(2) QALY change (death)	% QALY gained	
				(3) For premature death	(4) For disability while alive
2	Cancer	3820	3542	93	7
10	Circulatory	3462	2369	68	32
11	Respiratory	16,522	687	4	96
13	Gastrointestinal	4166	1536	37	63
1	Infectious diseases	1300	258	20	80
4	Endocrine	1143	63	5	95
7	Neurological	6421	264	4	96
17	Genitourinary	1224	247	20	80
16	Trauma and injuries	0	0	N/A	N/A
18 + 19	Maternity and neonates	7	5	69	31
3	Disorders of blood	2695	139	5	95
5	Mental health	8316	726	9	91
6	Learning disability	117	23	20	80
8	Problems of vision	600	24	4	96
9	Problems of hearing	956	7	1	99
12	Dental problems	444	0	0	100
14	Skin	98	36	37	63
15	Musculoskeletal	2926	145	5	95
20	Poisoning and adverse events	77	12	16	84
21	Healthy individuals	48	7	16	84
22	Social care needs	0	0	N/A	N/A
23	Other	0	0	N/A	N/A

N/A, not applicable.

Summary of the cost per quality-adjusted life-year threshold

TABLE 191 Summary of cost per QALY threshold estimates (2007)

PBC scenario	Cost per QALY
QoL associated with life extension	Based on burden
QoL during disease	Based on burden
Best estimate	
Effect of expenditure on mortality	1 year
YLL per death averted	~4.8
QALYs per death averted	~16.8
(1) All big four programmes	£4549
(2) 11 PBCs (with mortality)	£8513
(3) All 23 PBCs	**£13,554**
Lower bound	
Effect of expenditure on mortality	Remainder of disease duration
YLL per death averted	~4.8
QALYs per death averted	~16.8
(4) All big four programmes	£1116
(5) 11 PBCs (with mortality)	£1361
(6) All 23 PBCs	**£2436**
Upper bound	
Effect of expenditure on mortality:	1 year
YLL per death averted:	2
QALYs per death averted:	~7.0
(7) All big four programmes	£10,965
(8) 11 PBCs (with mortality)	£20,517
(9) All 23 PBCs	**£32,670**

TABLE 192 Summary of QALY threshold, discounted (2007)

PBC scenario	(1) 2007–9
(1) All big four programmes	£4690
(2) 11 PBCs	£8718
(3) All 23 PBCs	£13,801

Addendum 1: data sources

General Practice Research Database

General Practice Research Database contains over 3 million active patient records drawn from approximately 400 primary care practices in the UK. The Medicines and Healthcare products Regulatory Agency manages the data set. The database has clinical and prescription data and can provide information to support pharmacovigilance (indication, utilisation and risk/benefit profiles of drugs) and formal pharmacoepidemiological studies, including information on demographics, medical symptoms, therapy (medicines, vaccines, devices) and treatment outcomes.

As of 29 March 2012 GPRD changed to the CPRD, an expanded data set that represents 'The All England Data and Interventional Research Service'. CPRD was approached to provide information on the prevalence of disease by ICD-10 disease code. A sample set of data was analysed by researchers at Pharmatelligence[x] who were tasked with extracting data on prevalence of each disease state by ICD-10 code.

We were provided with access to data comprising of 22,313,086 rows/patient–ICD10 events (three digit)[y] representing 4,229,910 patients with data on new diagnosis of diseases observed between 1 January 2006 and 24 June 2011. Multiple events per patient are thus possible, and all patients are active in the data set (i.e. patients had at least one new diagnosis in the period of interest). Newly diagnosed (incident) events were defined using a wash-in period of 24 months (or from registration to index date if lower than 24 months). The sample contains 1873 unique ICD-10 codes in the data set. Seventy ICD-10 codes account for 50% of the total number of events, 166 for 75% and 306 for 90%.

Diagnoses are collected in CPRD using Read codes. These were mapped into three-character ICD-10 codes. Cross-mappings from Read V2 and Read V3 to ICD-10 were used in order to maximize the number of CPRD Read and ICD-10 codes included (33.2% of Read codes; 99.7% of ICD-10 codes).[z]

Unfortunately, due to the short collection period of CPRD it was not possible to directly observe prevalence only incidence over a period. Attempts were made to elicit a prevalence estimate through observed incidence data from CPRD coupled with clinical expertise on expected disease duration (provided by Dr Charlotte Haylock, York Teaching Hospital NHS Foundation Trust). Our approach classified expected duration for all ICD-10 diseases by three-digit code into one of five duration 'buckets'.[aa] However, the limitations of the data were deemed too extensive to provide sufficient accuracy of estimates to represent a stronger estimate of prevalence than provided by GBD.

Global Burden of Disease

The WHO GBD project draws on a wide range of data sources to quantify global and regional effects of diseases, injuries and risk factors on population health. We were provided with access to the beta version of the WHO's National Burden of Disease toolkit for the UK which represents a set of metrics on WHO prior estimates of mortality and burden of disease for WHO member states for 2004 (based on the GBD: 2004 update[155]).[ab]

The metrics of interest to our analysis included disease incidence, prevalence, duration and mortality. These metrics were provided by U-codes which were mapped to ICD-10 codes using direct WHO mapping algorithms.[157] In addition, in many cases each U-code was subdivided by disease sequelae which represent disease subcategories of each U-code.[157] As an individual may be represented in multiple sequelae in a single U-code to avoid double counting in the event of multiple sequelae in a given U-code our analysis uses prevalence estimates based on the sequelae with the largest prevalent population.

Our analysis uses two forms of prevalence data, 'point prevalence' and 'annual prevalence'. 'Point prevalence' represents the instantaneous prevalence of a disease whereas 'annual prevalence' represents the extent of the prevalence population over a given year. To calculate 'annual prevalence' incidence of a disease was multiplied by expected disease duration rounded up to the nearest year.

All data was provided by age, given for both genders in fixed age buckets (either 8 or 19 buckets depending on the data of interest), as a result it was necessary to assume the relevant population could be represented by the mid-point of that bucket for the relevant metric.

Health Survey for England

The HSE comprises a series of annual surveys beginning in 1991. This survey is now commissioned and published by The NHS IC. It is designed to provide regular information on various aspects of the nation's health. All surveys have covered the adult population aged 16 years and over living in private households in England.[ac]

In order to define the QoL norms for the population of the UK required for the analysis detailed in *Chapter 4, Quality of life based on the general population*, data from six Health Surveys for England (1996, 2003, 2004, 2005, 2006 and 2008) were pooled. Self-reported health status and EQ-5D data were extracted and used to generate mean health state utility values for the 'normal' population.

Surveys are not completed for people age under 16 years; as a result we have assumed that all persons aged 0–15 years have the same QoL norms as a person aged 16 years. In addition the number of surveys recorded for persons over 91 years of age is relatively small; as a result all persons aged over 91 years are assumed to have the same QoL norm as a person aged 91 years. The QoL norms for each age and gender are shown in *Figure 3* in *Quality of life based on the general population*.

Health Outcomes Data Repository

Health Outcomes Data Repository represents a supplement of routine clinically coded data from the Cardiff and Vale NHS Hospitals Trust, UK, with survey data covering sociodemographic characteristics, QoL, utility and resource use information.[93] HODaR data were collected for subjects treated at Cardiff and Vale NHS Hospital from 2002 to 2004. Inpatients were surveyed 6 weeks post-discharge while outpatients are handed a survey package when they attend. More than 30,000 observations (aged $\geq$ 18 years) are available relating to approximately 2000 diagnoses of disease by ICD-10 code.

We used HODaR to estimate health-related QoL by ICD-10 diagnoses codes and age using EQ-5D. If data on a patient were provided with multiple diagnoses the primary condition was used.

Medical Expenditure Panel Survey

MEPS is a national representative survey of the US civilian non-institutionalised population, collecting information on health-care utilisation which began in 1996.[94] EQ-5D was employed to measure health-related QoL of the population in years 2000–2. There are about 38,000 adults (aged $\geq$ 18 years) completing EQ-5D relating to 700 ICD-10 code diagnoses. MEPS consists of a household component and an insurance component, both aimed at identifying the medical usage of individuals as well as how they are funded, their cost, and the scope and breadth of health insurance held and available.

As with HODaR, MEPS allowed us to estimate the health-related QoL by ICD-10 code and age. If data on a patient was provided with multiple conditions the primary condition was used.

Hospital Episode Statistics

Hospital Episode Statistics represents a collection of data with details on all admissions to the NHS hospital in England. It contains admitted patient care data from 1989 onwards, with more than 12 million new records added each year, and outpatient attendance data from 2003 onwards, with more than 40 million new records added each year.

Expenditure by ICD-10 codes and PCT was used to estimate the contribution to variance of each PBC. This was done by calculating the contribution of that ICD-10 code to the variance in expenditure between PCTs within a PBC (total costs allocated to individual ICD-10 codes were divided by the number of patients using services in the PCT). For our analysis we make use of HES data on the year 2007/8.

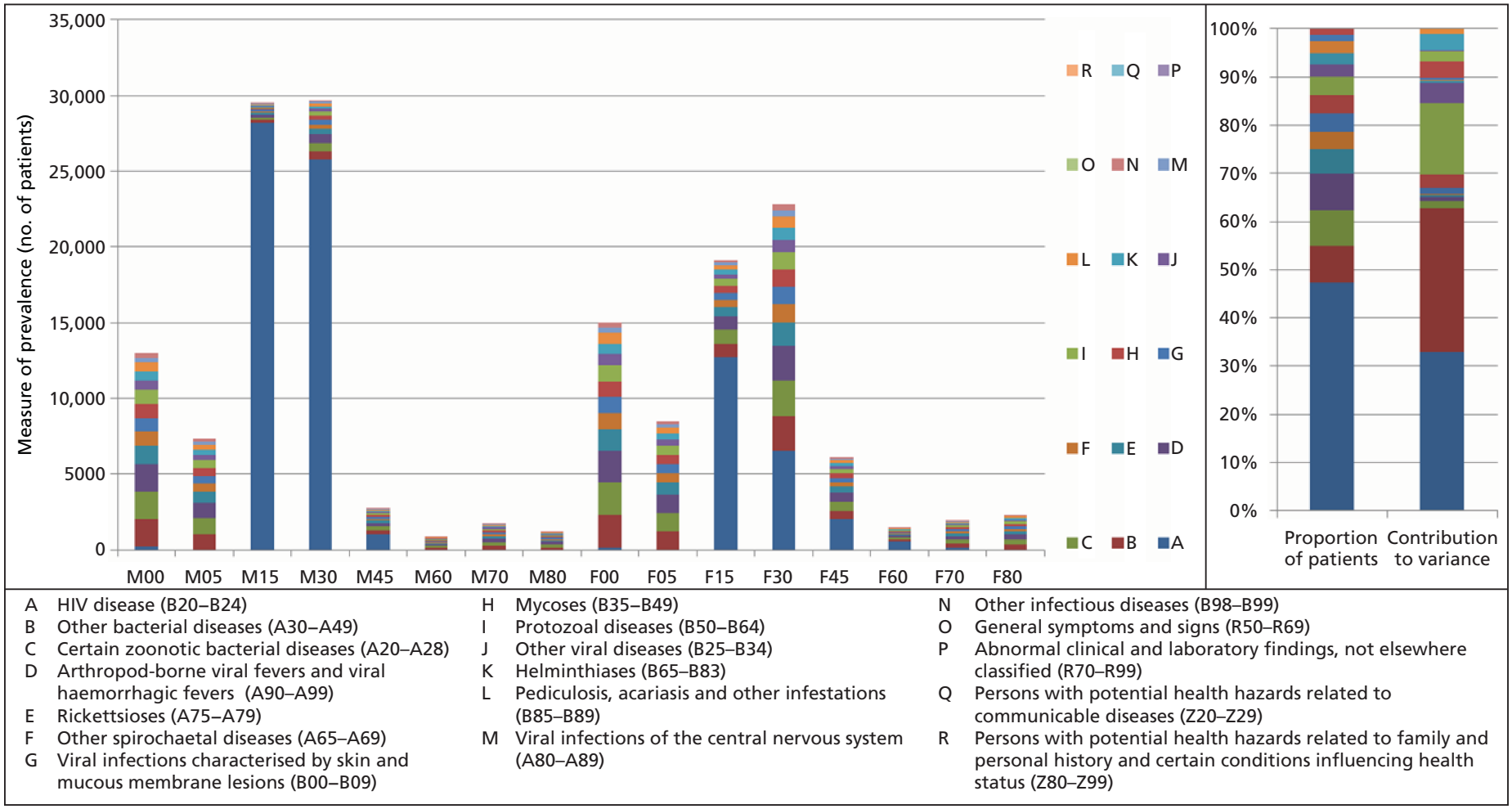
Patient-reported outcome measures

Introduced in 2009, the English NHS PROMs programme routinely collects self-reported health status of patients receiving surgery for four elective procedures: knee and hip replacement, groin hernia repair, and varicose vein surgery. Patients are invited to complete a questionnaire prior to surgery, and again 6 (or 3) months after surgery.[159] Differences in their self-reported health status are used to explore differences between provider performance in improving patient health.[160] The data that are collected include both condition-specific questions (the Oxford Hip Score, Oxford Knee Score and the Aberdeen Varicose Vein score; no condition-specific instrument is available for hernia) as well as the generic instrument, the EQ-5D (both the EQ-5D profile and the patient's global assessment of their health, the EQ-VAS[161]). All NHS patients receiving these surgical procedures are invited to complete the PROMs questionnaires – in practice, for a variety of reasons, some patients do not participate, or complete only the pre-surgery, or the post-surgery, questionnaire – so the data do not cover 100% of patients. However, good coverage rates have been achieved (e.g. the response rate from hip surgery patients to April 2012 was 78% for the pre-surgery questionnaire, and 81% for the post-surgery questionnaire).[162]

Patient-level data from the PROMs programme are freely available to download in anonymised form. Those data can also be linked to further information in the HES database, via requests to the NHS IC. Standardised reports on the PROMs data, including the average (case-mix adjusted) performance of providers, is regularly published by the NHS IC, currently on a quarterly basis.

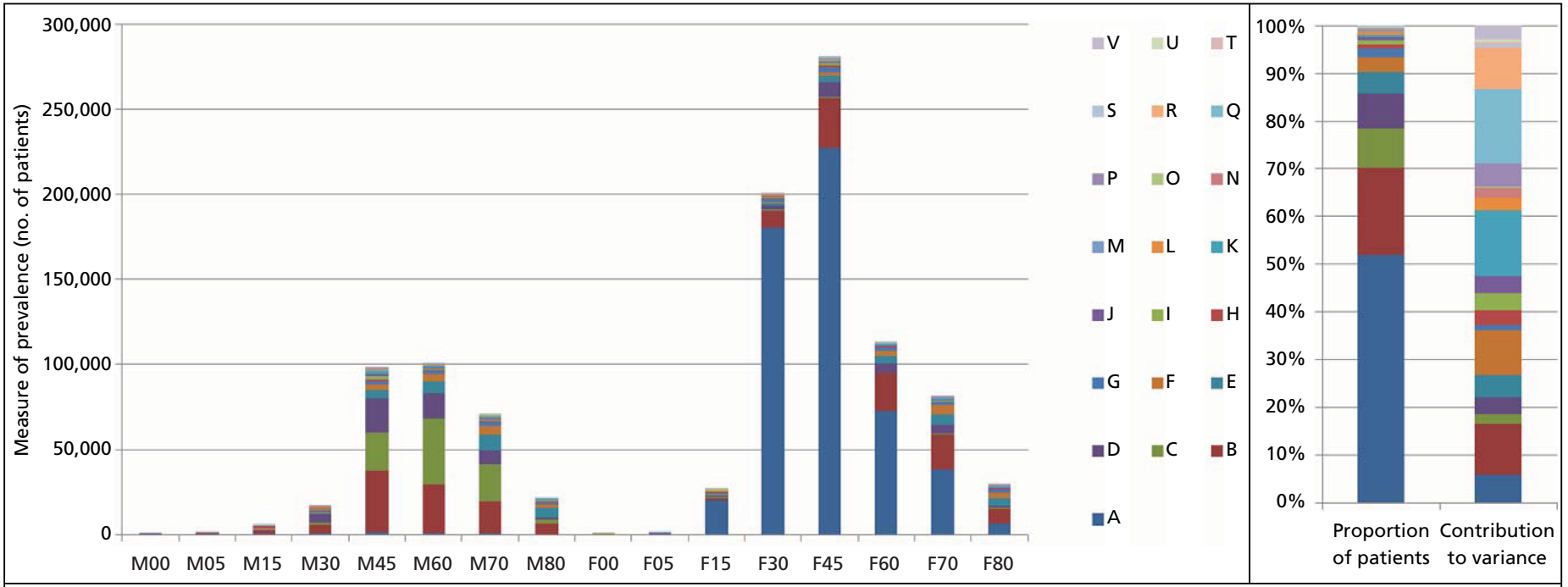
There are plans to extend the PROMs programme in the future, in keeping with the Government's NHS Outcomes Framework, and a number of pilot studies have been commissioned by the Department of Health in order to inform the roll-out to other NHS services. There is currently work under way around the potential use of PROMs in a wide range of long-term conditions; primary care; cancer survivorship; cardiovascular services; musculoskeletal; and cosmetic surgery.

Figures of prevalence distribution within programme budget categories



A HIV disease (B20–B24)
B Other bacterial diseases (A30–A49)
C Certain zoonotic bacterial diseases (A20–A28)
D Arthropod-borne viral fevers and viral haemorrhagic fevers (A90–A99)
E Rickettsioses (A75–A79)
F Other spirochaetal diseases (A65–A69)
G Viral infections characterised by skin and mucous membrane lesions (B00–B09)
H Mycoses (B35–B49)
I Protozoal diseases (B50–B64)
J Other viral diseases (B25–B34)
K Helminthiases (B65–B83)
L Pediculosis, acariasis and other infestations (B85–B89)
M Viral infections of the central nervous system (A80–A89)
N Other infectious diseases (B98–B99)
O General symptoms and signs (R50–R69)
P Abnormal clinical and laboratory findings, not elsewhere classified (R70–R99)
Q Persons with potential health hazards related to communicable diseases (Z20–Z29)
R Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)

FIGURE 55 Distribution of PBC 1 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A Malignant neoplasms, breast and female genital organs (C50–C58)
B Malignant neoplasms, digestive organs (C15–C26)
C Malignant neoplasms, human male genital organs (C60–C63)
D Malignant neoplasms, urinary organs (C64–C68)
E Malignant neoplasms, respiratory system and intrathoracic organs (C30–C39)
F Malignant neoplasms, stated or presumed to be primary, of lymphoid, haematopoietic and related tissue (C81–C96)
G Malignant neoplasms, skin (C43–C44)
H Malignant neoplasms, connective and soft tissue (C45–C49)
I Malignant neoplasms, secondary and ill-defined (C76–C80)
J Malignant neoplasms, eye, brain and central nervous system (C69–C72)
K Malignant neoplasms, lip, oral cavity and pharynx (C00–C14)
L Malignant neoplasms, endocrine glands and related structures (C73–C75)
M Other diseases of the respiratory system (J95–J99)
N Malignant neoplasms, bone and articular cartilage (C40–C41)
O Malignant neoplasms of independent (primary) multiple sites (C97)
P In situ neoplasms (D00–D09)
Q Benign neoplasms (D10–D36)
R Neoplasms of uncertain or unknown behaviour (D37–D48)
S Other diseases of urinary system (N30–N39)
T Persons encountering health services for examination and investigation (Z00–Z13)
U Persons encountering health services for specific procedures and health care (Z40–Z54)
V Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)

FIGURE 56 Distribution of PBC 2 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

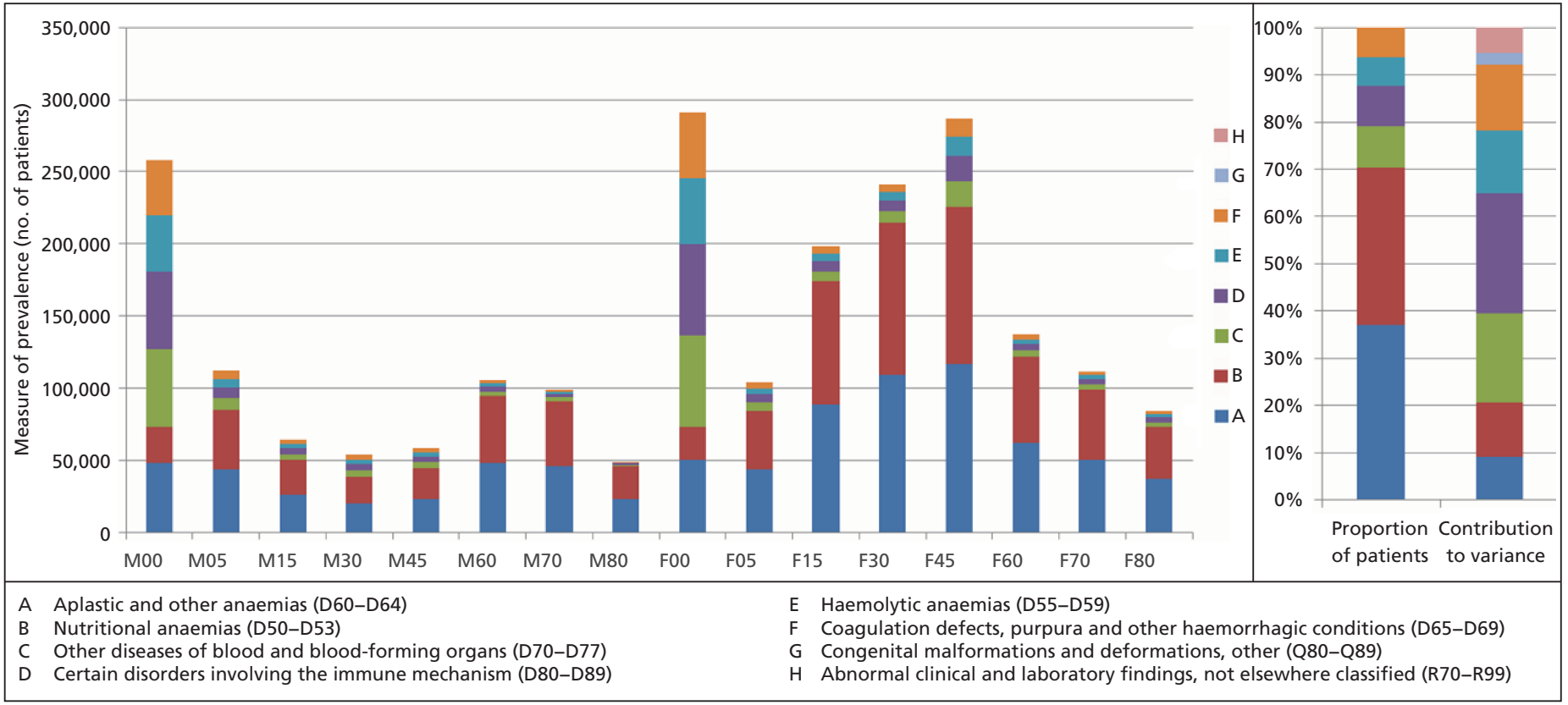


FIGURE 57 Distribution of PBC 3 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

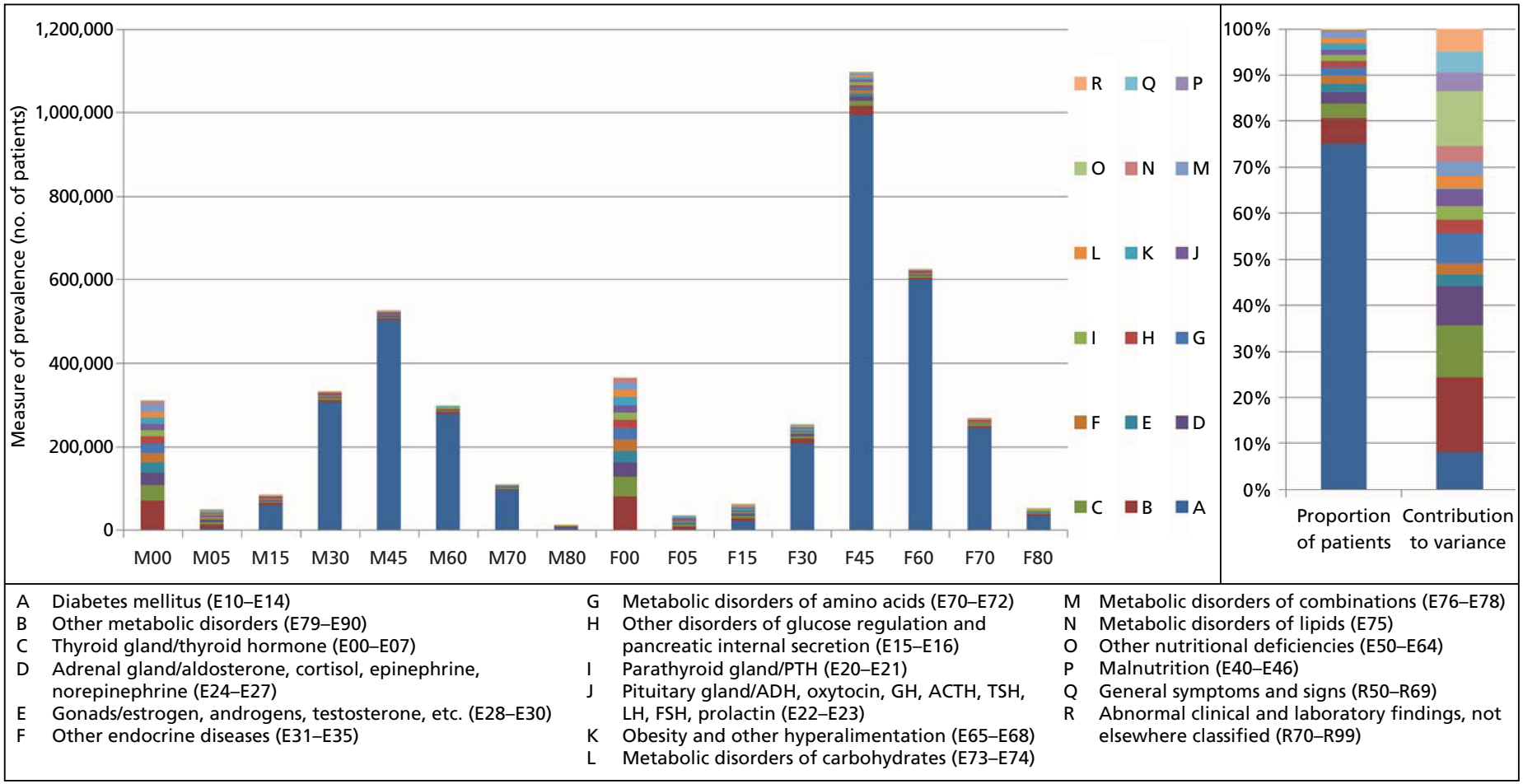
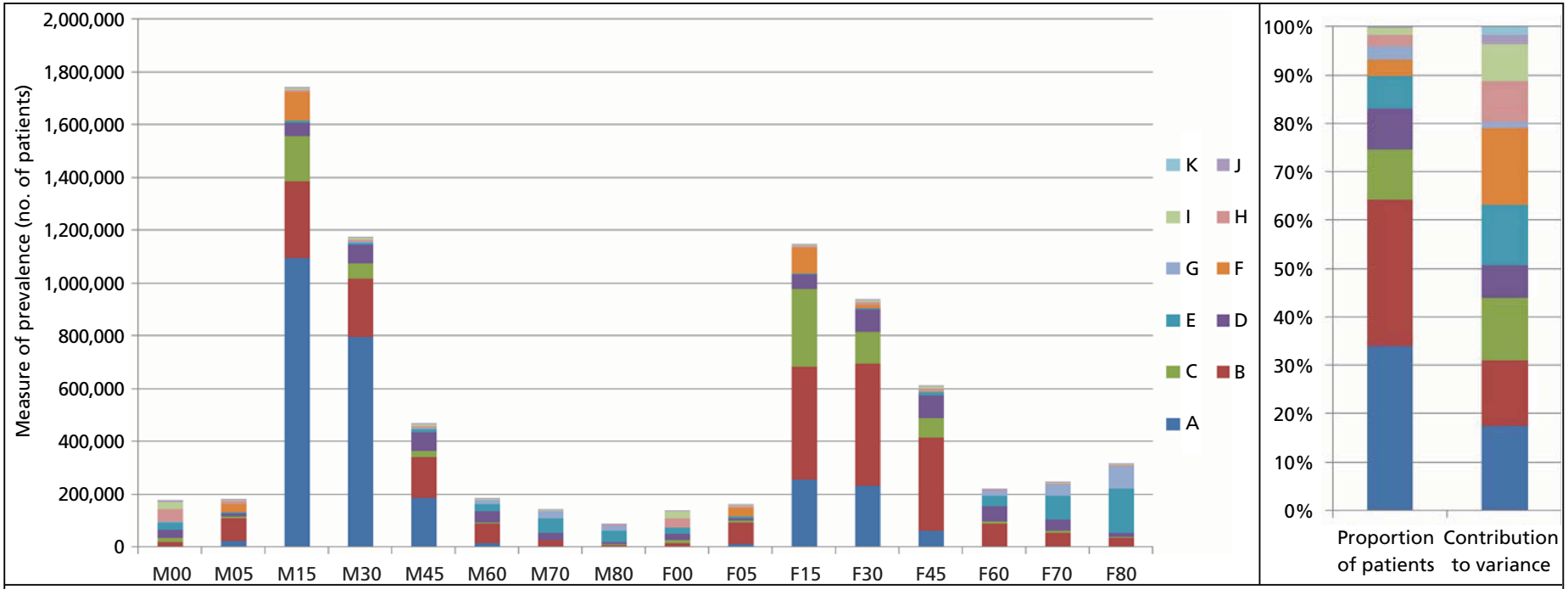


FIGURE 58 Distribution of PBC 4 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. ACTH, adrenocorticotrophic hormone; ADH, antidiuretic hormone; FSH, follicle-stimulating hormone; GH, growth hormone; LH, luteinising hormone; PTH, parathyroid hormone; TSH, thyroid-stimulating hormone. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A Mental and behavioural disorders due to psychoactive substance use (F10–F19)
B Mood (affective) disorders (F30–F39)
C Neurotic, stress-related and somatoform disorders (F40–F48)
D Behavioural syndromes associated with physiological disturbances and physical factors (F50–F59)
E Organic, including symptomatic, mental disorders (F00–F09)
F Schizophrenia, schizotypal and delusional disorders (F20–F29)
G Other degenerative diseases of the nervous system (G30–G32)
H Disorders of adult personality and behaviour (F60–F69)
I Behavioural and emotional disorders with onset usually occurring in childhood and adolescence (F90–F98)
J Unspecified mental disorder (F99)
K Persons with potential health hazards related to socio-economic and psychosocial circumstances (Z55–Z65)

FIGURE 59 Distribution of PBC 5 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

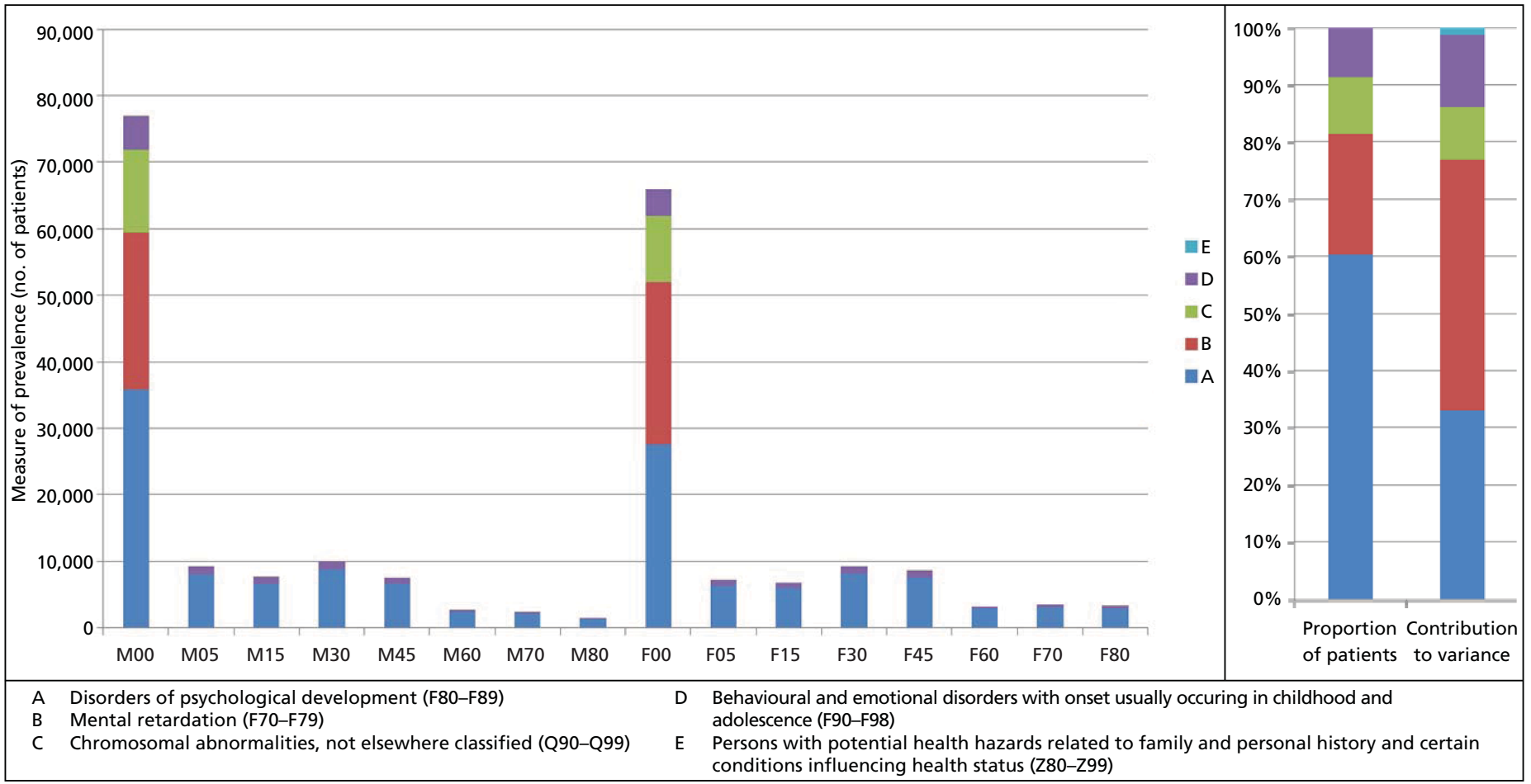
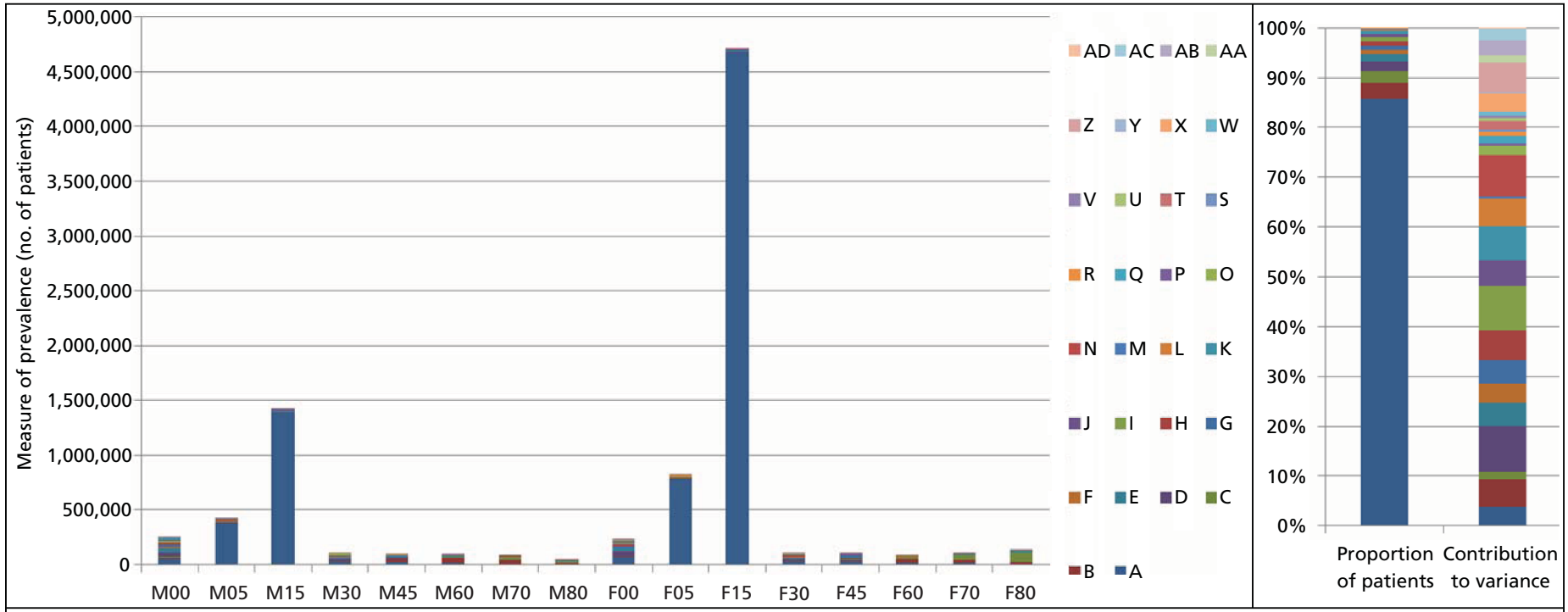
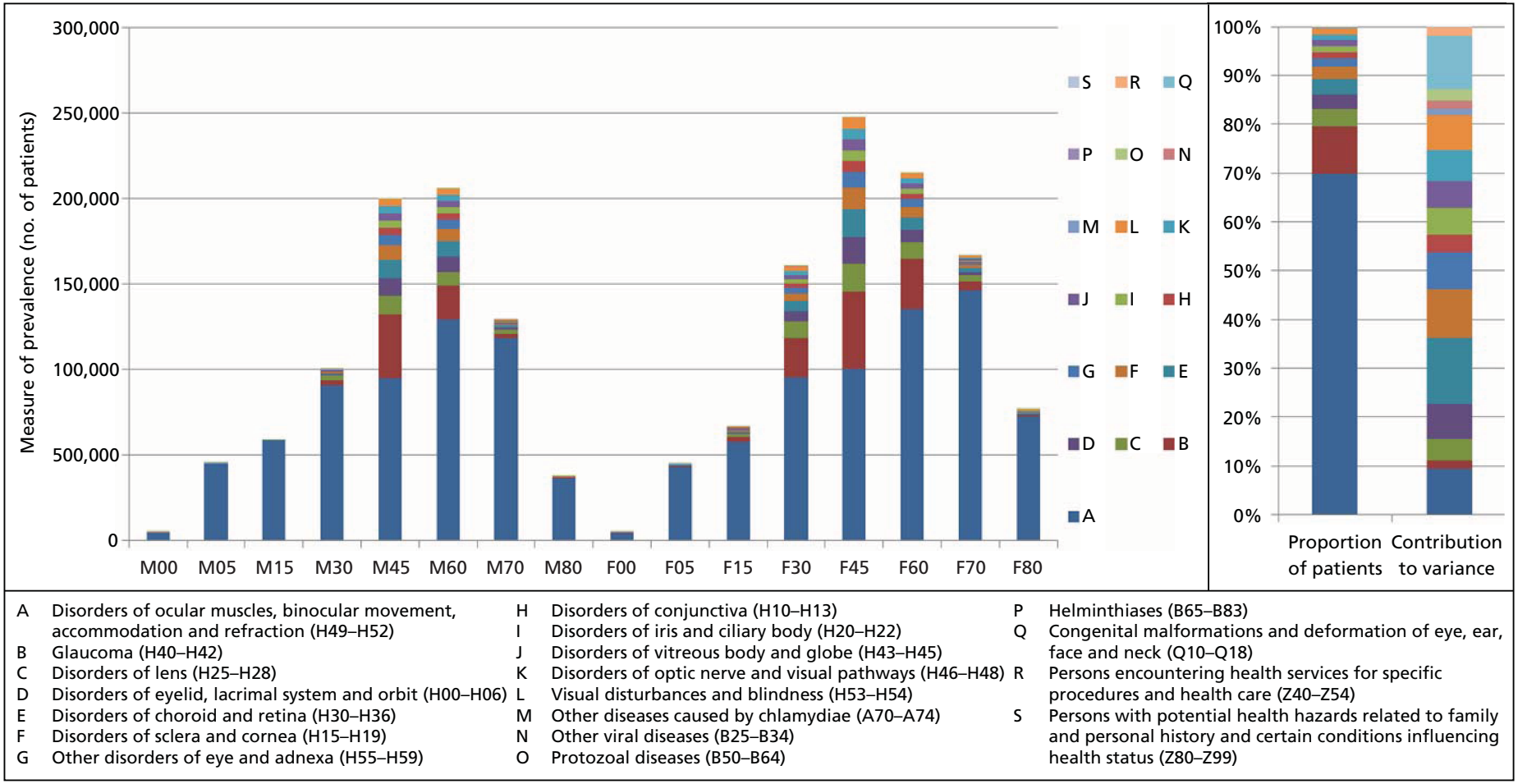


FIGURE 60 Distribution of PBC 6 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A	Episodic and paroxysmal disorders (G40–G47)	J	Systemic atrophies primarily affecting the central nervous system (G10–G13)	R	Other viral diseases (B25–B34)	Z	Symptoms and signs of cognition, perception emotional state and behaviour (R40–R46)
B	Extrapyramidal and movement disorders (G20–G26)	K	Diseases of myoneural junction and muscle (G70–G73)	S	Helminthiases (B65–B83)		
C	Other degenerative diseases of the nervous system (G30–G32)	L	Viral infections of the central nervous system (A80–A89)	T	Tuberculosis (A15–A19)	AA	Symptoms and signs of speech and voice (R47–R49)
D	Other disorders of the nervous system (G90–G99)	M	Other disorders of the ear (H90–H95)	U	Protozoal diseases (B50–B64)	AB	General symptoms and signs (R50–R69)
E	Nerve, nerve root and plexus disorders (G50–G59)	N	Congenital malformations and deformations of the nervous system (Q00–Q07)	V	Symptoms and signs of circulatory and respiratory systems (R00–R09)	AC	Abnormal clinical and laboratory findings, not elsewhere classified (R70–R99)
F	Demyelinating diseases of the central nervous system (G35–G37)	O	Viral infections characterised by skin and mucous membrane lesions (B00–B09)	W	Symptoms and signs of skin and subcutaneous tissue (R20–R23)	AD	Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)
G	Polyneuropathies and other disorders of the peripheral nervous system (G60–G64)	P	Other diseases of the urinary system (N30–N39)	X	Symptoms and signs of nervous and musculoskeletal systems (R25–R29)		
H	Cerebral palsy and other paralytic syndromes (G80–G83)	Q	Other bacterial diseases (A30–A49)	Y	Symptoms and signs of urinary system (R30–R39)		
I	Inflammatory diseases of the central nervous system (G00–G09)						

FIGURE 61 Distribution of PBC 7 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A	Disorders of ocular muscles, binocular movement, accommodation and refraction (H49–H52)	H	Disorders of conjunctiva (H10–H13)	P	Helminthiases (B65–B83)
B	Glaucoma (H40–H42)	I	Disorders of iris and ciliary body (H20–H22)	Q	Congenital malformations and deformation of eye, ear, face and neck (Q10–Q18)
C	Disorders of lens (H25–H28)	J	Disorders of vitreous body and globe (H43–H45)	R	Persons encountering health services for specific procedures and health care (Z40–Z54)
D	Disorders of eyelid, lacrimal system and orbit (H00–H06)	K	Disorders of optic nerve and visual pathways (H46–H48)	S	Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)
E	Disorders of choroid and retina (H30–H36)	L	Visual disturbances and blindness (H53–H54)		
F	Disorders of sclera and cornea (H15–H19)	M	Other diseases caused by chlamydiae (A70–A74)		
G	Other disorders of eye and adnexa (H55–H59)	N	Other viral diseases (B25–B34)		
		O	Protozoal diseases (B50–B64)		

FIGURE 62 Distribution of PBC 8 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

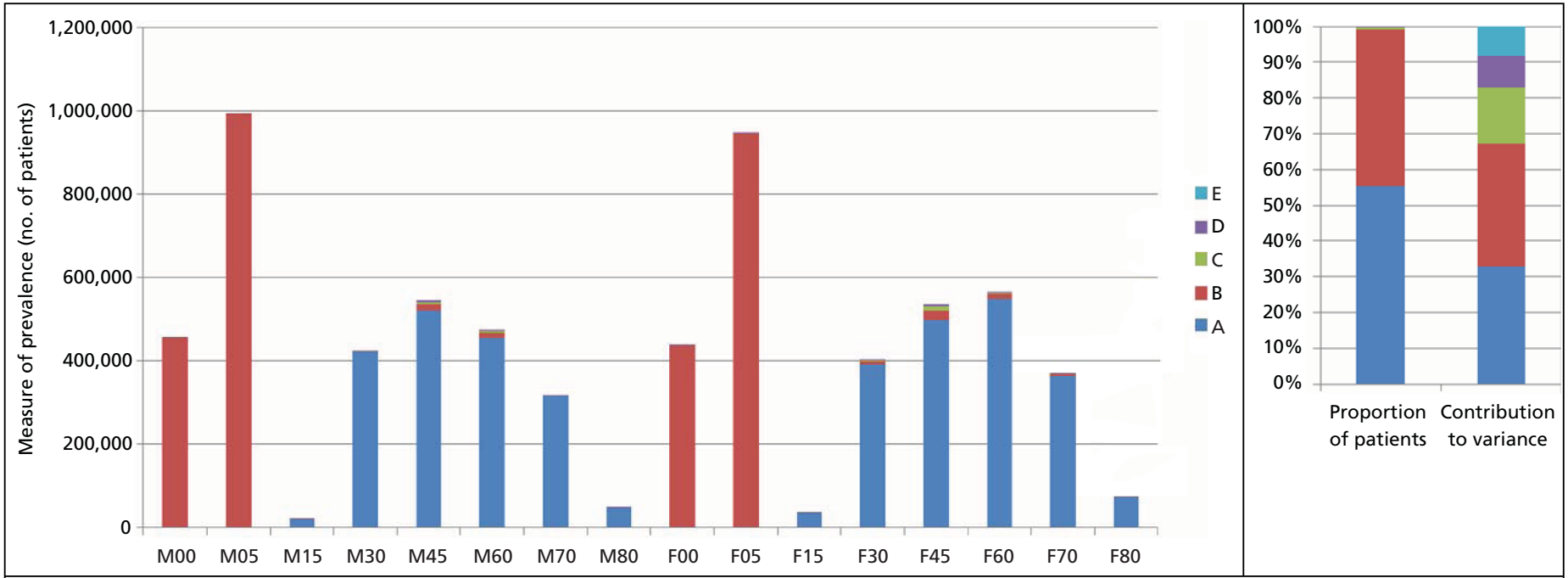


FIGURE 63 Distribution of PBC 9 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

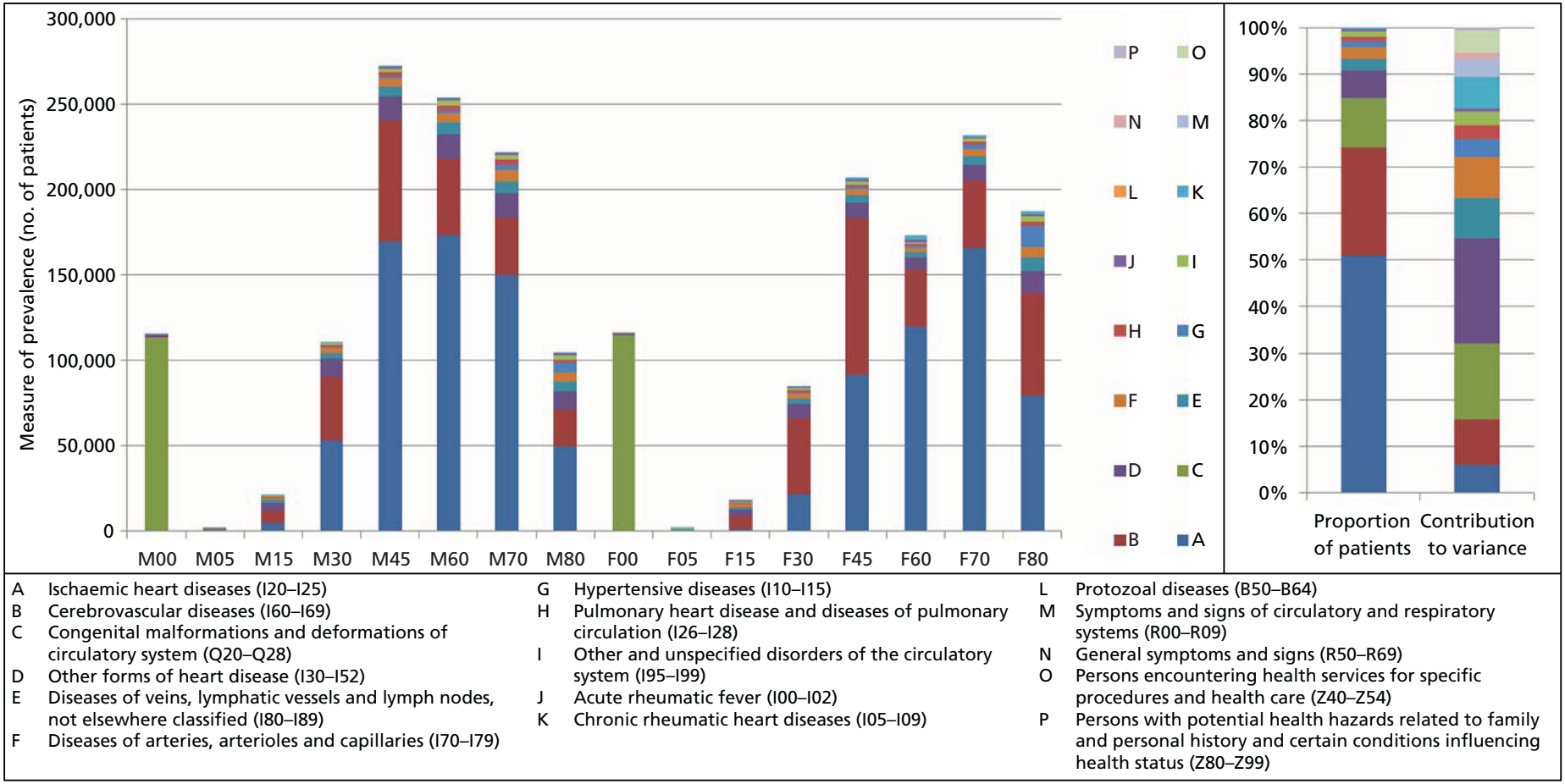
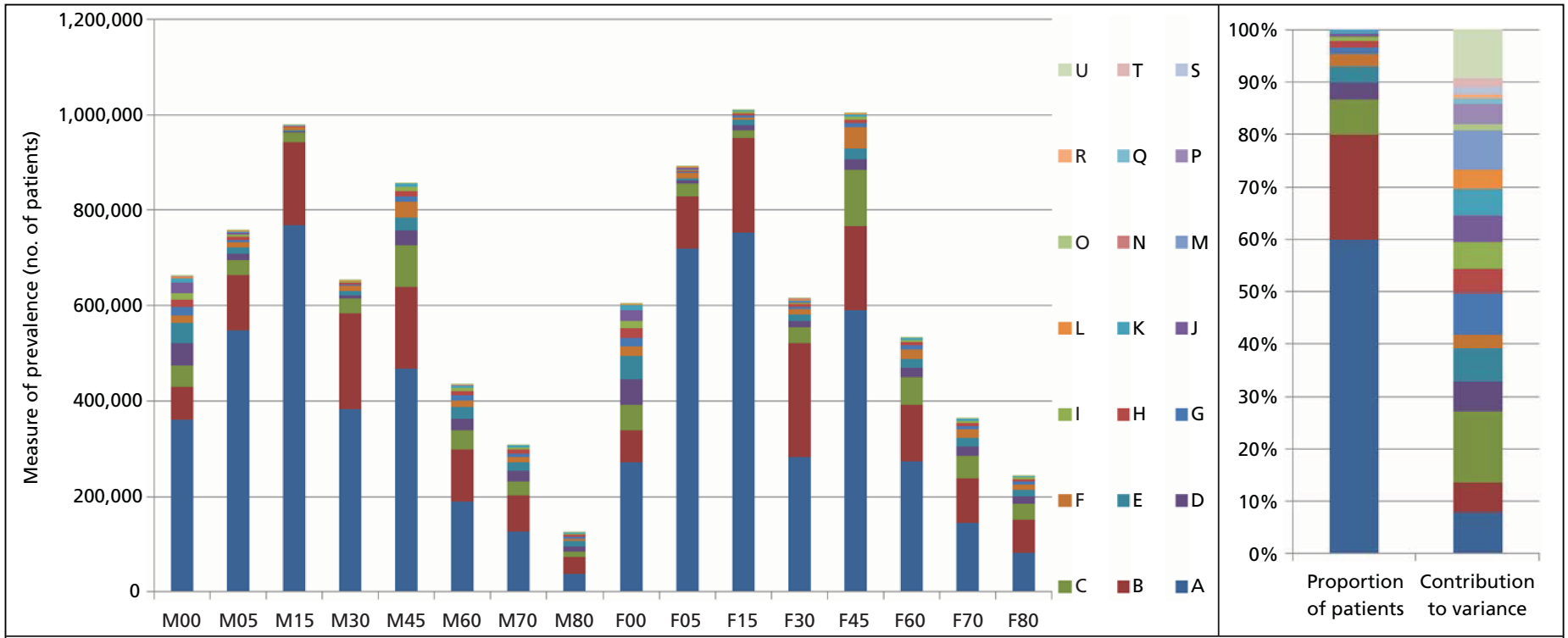


FIGURE 64 Distribution of PBC 10 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A Chronic lower respiratory diseases (J40–J47)
B Acute upper respiratory infections (J00–J06)
C Influenza and pneumonia (J09–J18)
D Lung diseases due to external agents (J60–J70)
E Other diseases of upper respiratory tract (J30–J39)
F Other acute lower respiratory infections (J20–J22)
G Other respiratory diseases principally affecting the interstitium (J80–J84)
H Other diseases of pleura (J90–J94)
I Other diseases of the respiratory system (J95–J99)
J Other bacterial diseases (A30–A49)
K Suppurative and necrotic conditions of lower respiratory tract (J85–J86)
L Mycoses (B35–B49)
M Tuberculosis (A15–A19)
N Other diseases caused by chlamydiae (A70–A74)
O Other viral diseases (B25–B34)
P Symptoms and signs of circulatory and respiratory systems (R00–R09)
Q Abnormal clinical and laboratory findings, not elsewhere classified (R70–R99)
R Persons encountering health services for examination and investigation (Z00–Z13)
S Persons encountering health services for specific procedures and health care (Z40–Z54)
T Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)
U Congenital malformations and deformations of the respiratory system (Q30–Q34)

FIGURE 65 Distribution of PBC 11 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

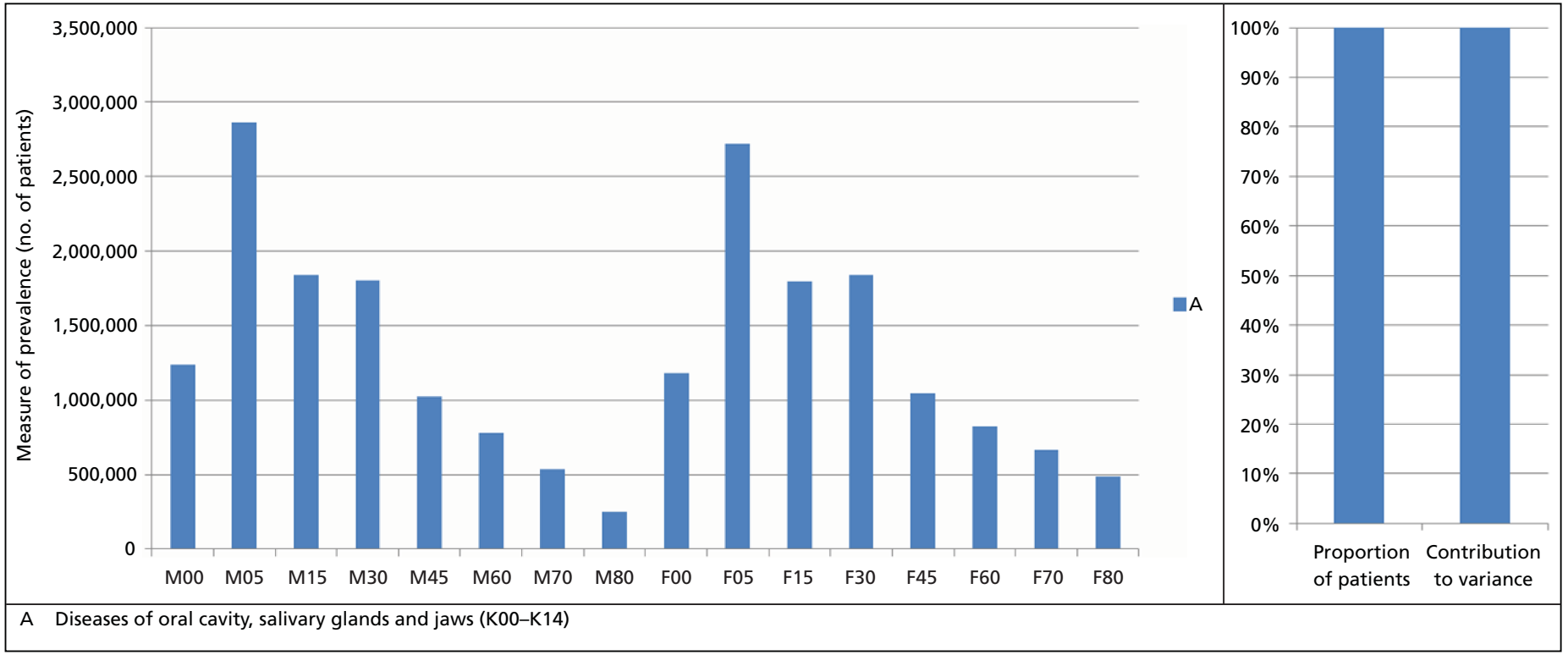
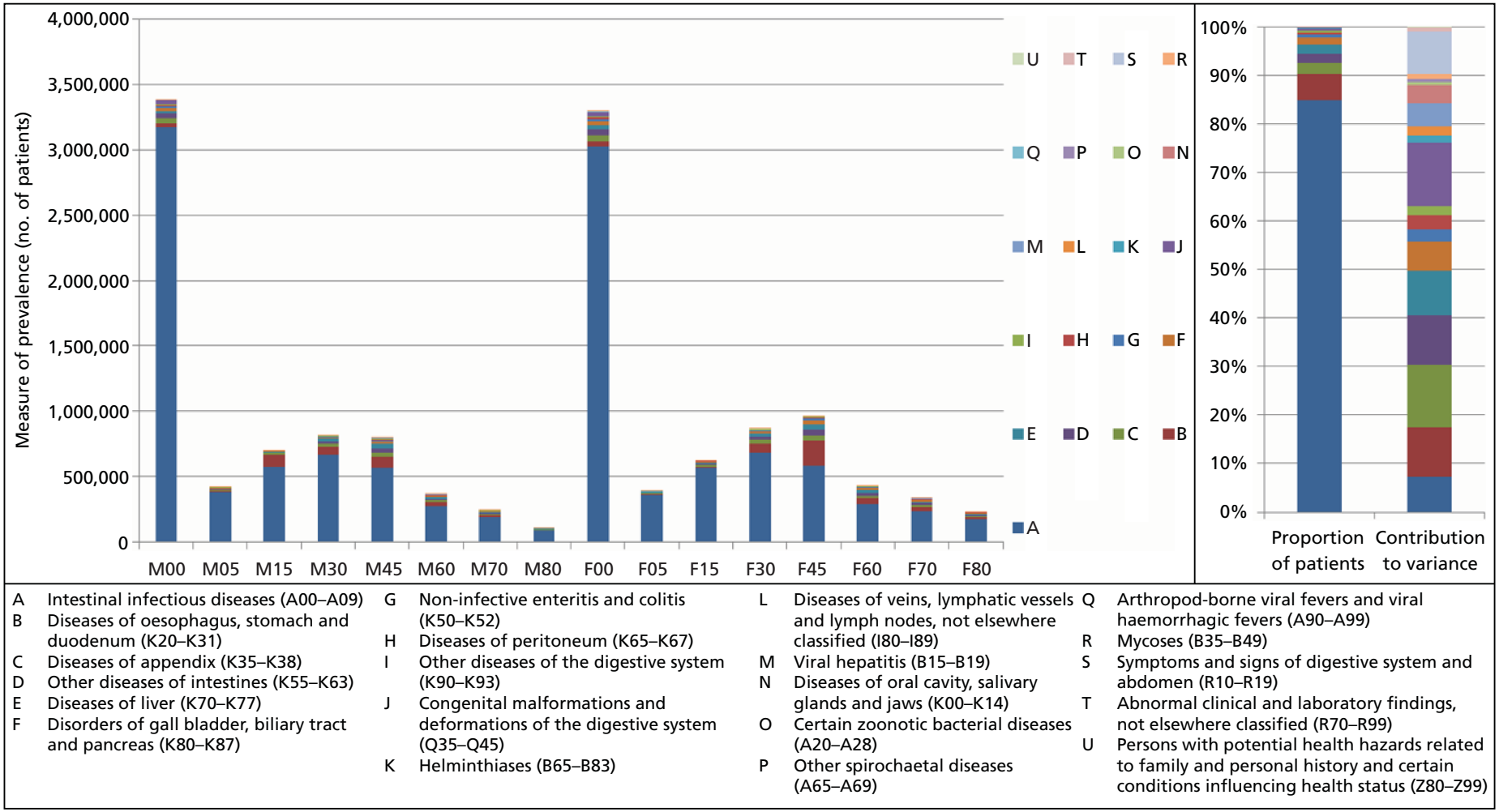


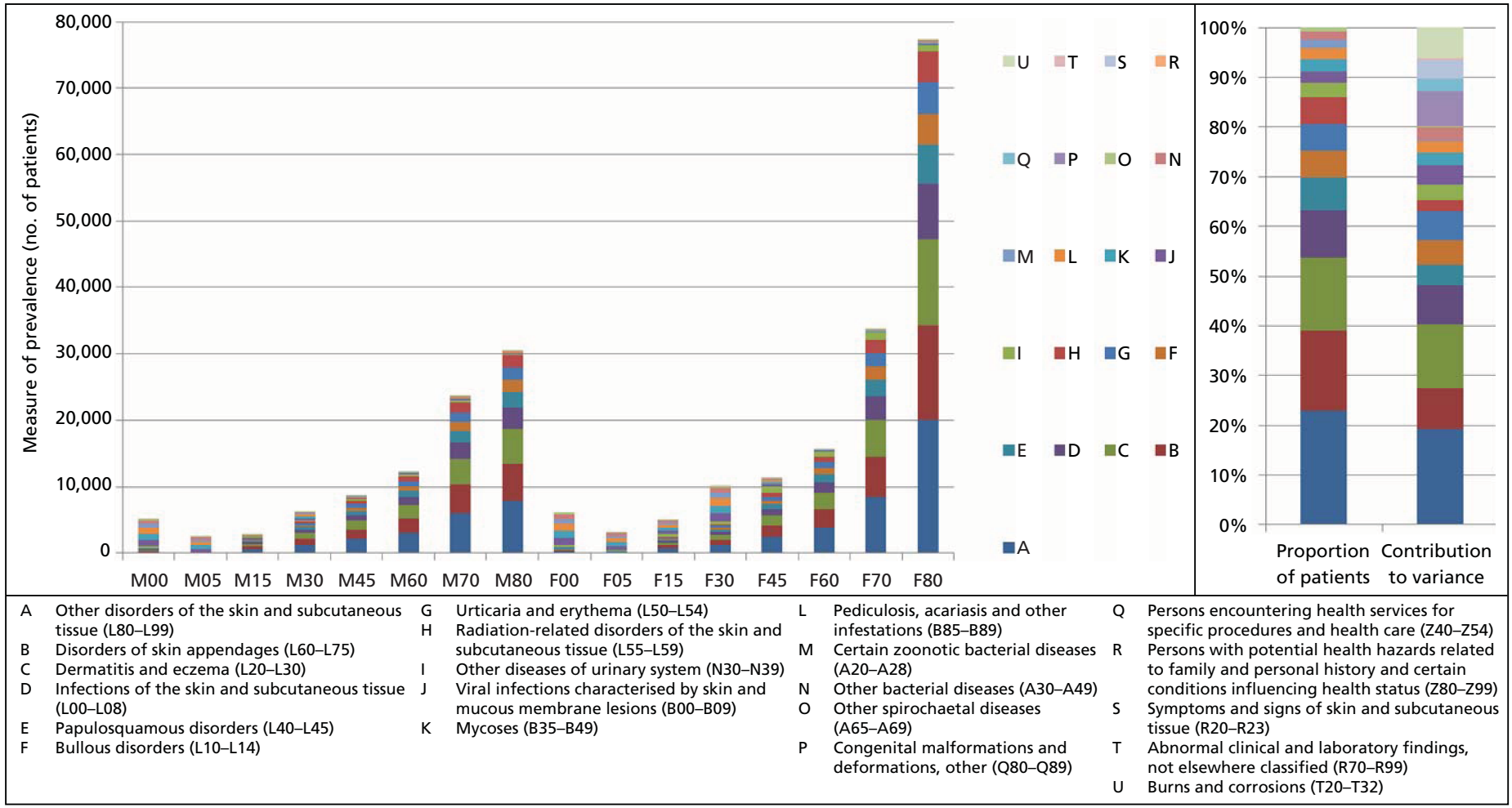
FIGURE 66 Distribution of PBC 12 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A	Intestinal infectious diseases (A00–A09)	G	Non-infective enteritis and colitis (K50–K52)	L	Diseases of veins, lymphatic vessels and lymph nodes, not elsewhere classified (I80–I89)
B	Diseases of oesophagus, stomach and duodenum (K20–K31)	H	Diseases of peritoneum (K65–K67)	M	Viral hepatitis (B15–B19)
C	Diseases of appendix (K35–K38)	I	Other diseases of the digestive system (K90–K93)	N	Diseases of oral cavity, salivary glands and jaws (K00–K14)
D	Other diseases of intestines (K55–K63)	J	Congenital malformations and deformations of the digestive system (Q35–Q45)	O	Certain zoonotic bacterial diseases (A20–A28)
E	Diseases of liver (K70–K77)	K	Helminthiases (B65–B83)	P	Other spirochaetal diseases (A65–A69)
F	Disorders of gall bladder, biliary tract and pancreas (K80–K87)				

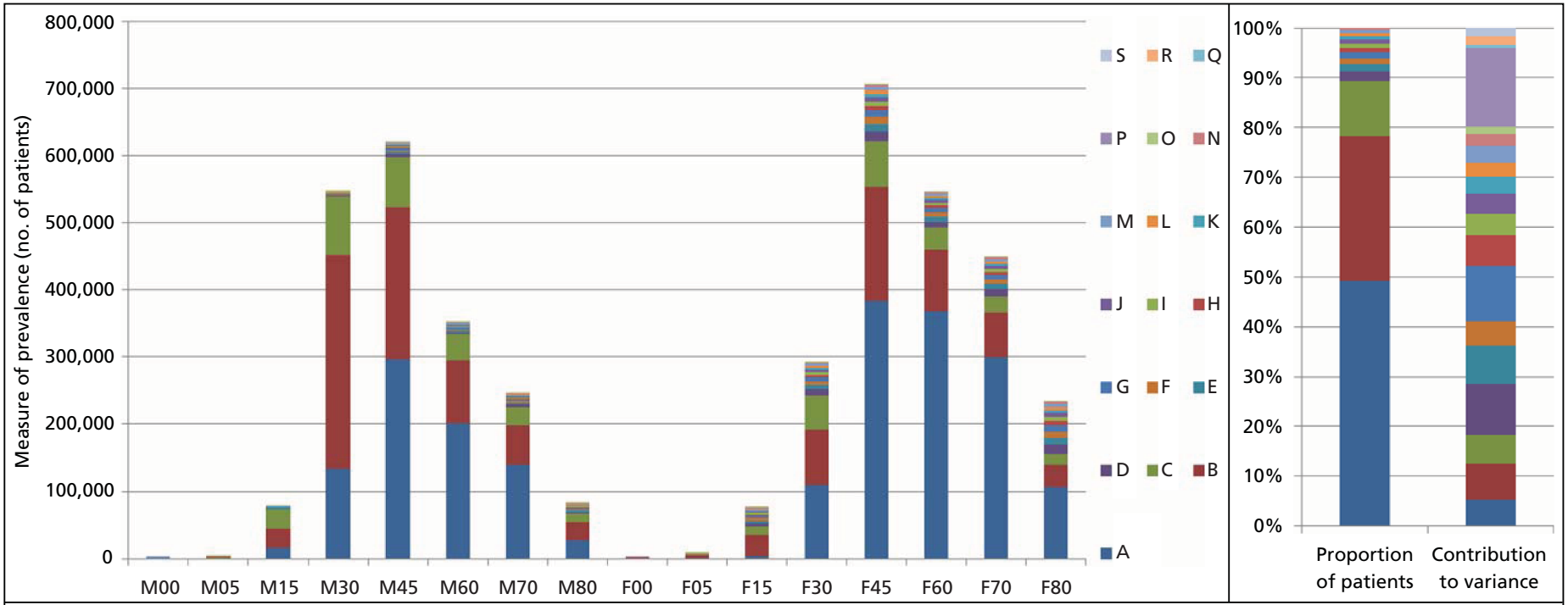
Q	Arthropod-borne viral fevers and viral haemorrhagic fevers (A90–A99)
R	Mycoses (B35–B49)
S	Symptoms and signs of digestive system and abdomen (R10–R19)
T	Abnormal clinical and laboratory findings, not elsewhere classified (R70–R99)
U	Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)

FIGURE 67 Distribution of PBC 13 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A Other disorders of the skin and subcutaneous tissue (L80–L99)
B Disorders of skin appendages (L60–L75)
C Dermatitis and eczema (L20–L30)
D Infections of the skin and subcutaneous tissue (L00–L08)
E Papulosquamous disorders (L40–L45)
F Bullous disorders (L10–L14)
G Urticaria and erythema (L50–L54)
H Radiation-related disorders of the skin and subcutaneous tissue (L55–L59)
I Other diseases of urinary system (N30–N39)
J Viral infections characterised by skin and mucous membrane lesions (B00–B09)
K Mycoses (B35–B49)
L Pediculosis, acariasis and other infestations (B85–B89)
M Certain zoonotic bacterial diseases (A20–A28)
N Other bacterial diseases (A30–A49)
O Other spirochaetal diseases (A65–A69)
P Congenital malformations and deformations, other (Q80–Q89)
Q Persons encountering health services for specific procedures and health care (Z40–Z54)
R Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)
S Symptoms and signs of skin and subcutaneous tissue (R20–R23)
T Abnormal clinical and laboratory findings, not elsewhere classified (R70–R99)
U Burns and corrosions (T20–T32)

FIGURE 68 Distribution of PBC 14 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A Arthrosis (M15–M19)
B Inflammatory polyarthropathies (M05–M14)
C Spondylopathies (M45–M49)
D Osteopathies (M80–M90)
E Other soft tissue disorders (M70–M79)
F Other joint disorders (M20–M25)
G Systemic connective tissue disorders (M30–M36)
H Deforming dorsopathies (M40–M43)
I Other dorsopathies (M50–M54)
J Chondropathies (M91–M94)
K Disorders of muscles (M60–M63)
L Disorders of synovium and tendon (M65–M68)
M Other disorders of the musculoskeletal system and connective tissue (M95–M99)
N Infectious arthropathies (M00–M03)
O Tuberculosis (A15–A19)
P Congenital malformations and deformations of musculoskeletal system (Q65–Q79)
Q Congenital malformations and deformation of eye, ear, face and neck (Q10–Q18)
R Congenital malformations and deformations, other (Q80–Q89)
S Persons encountering health services for specific procedures and health care (Z40–Z54)

FIGURE 69 Distribution of PBC 15 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

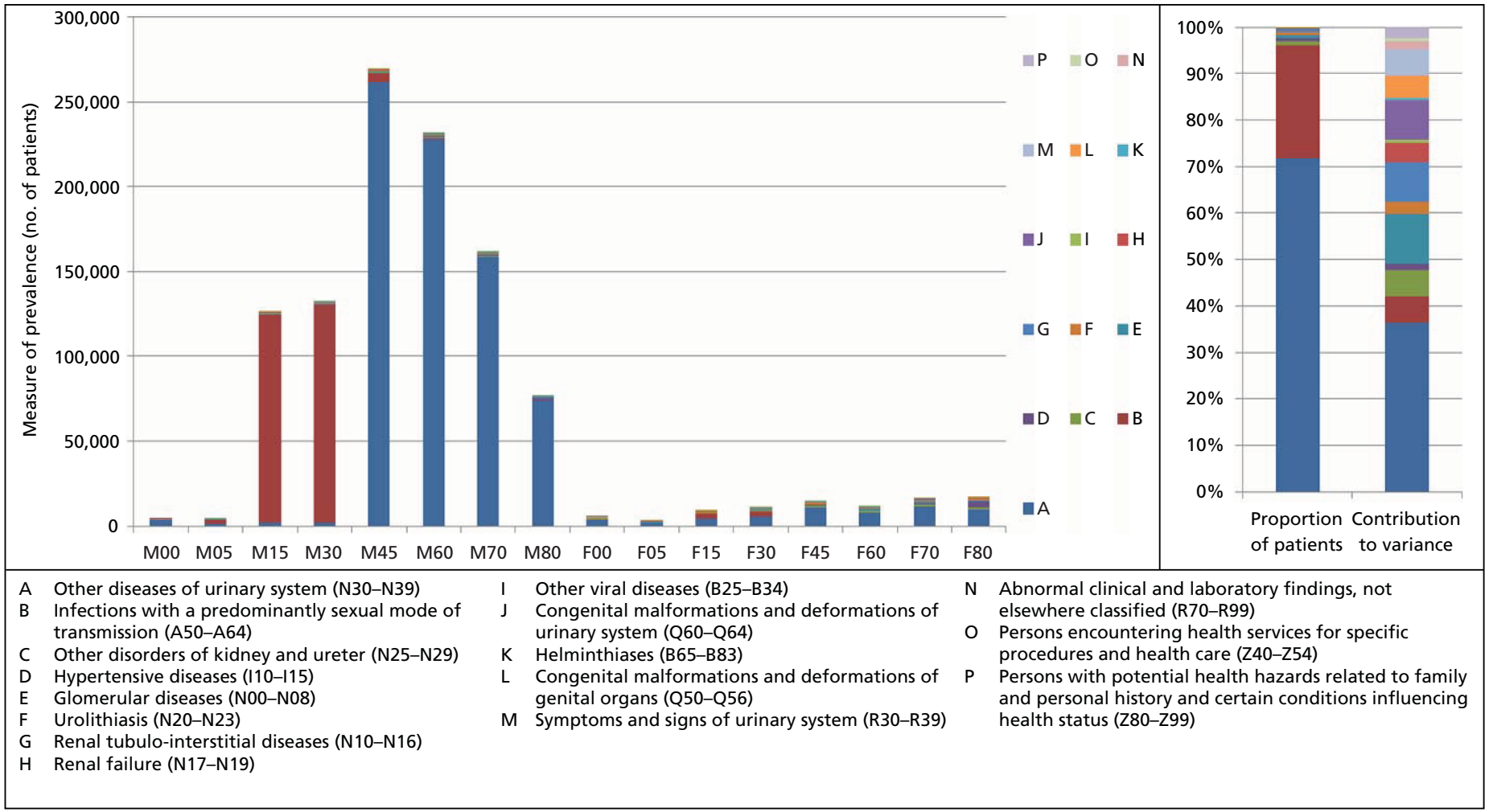
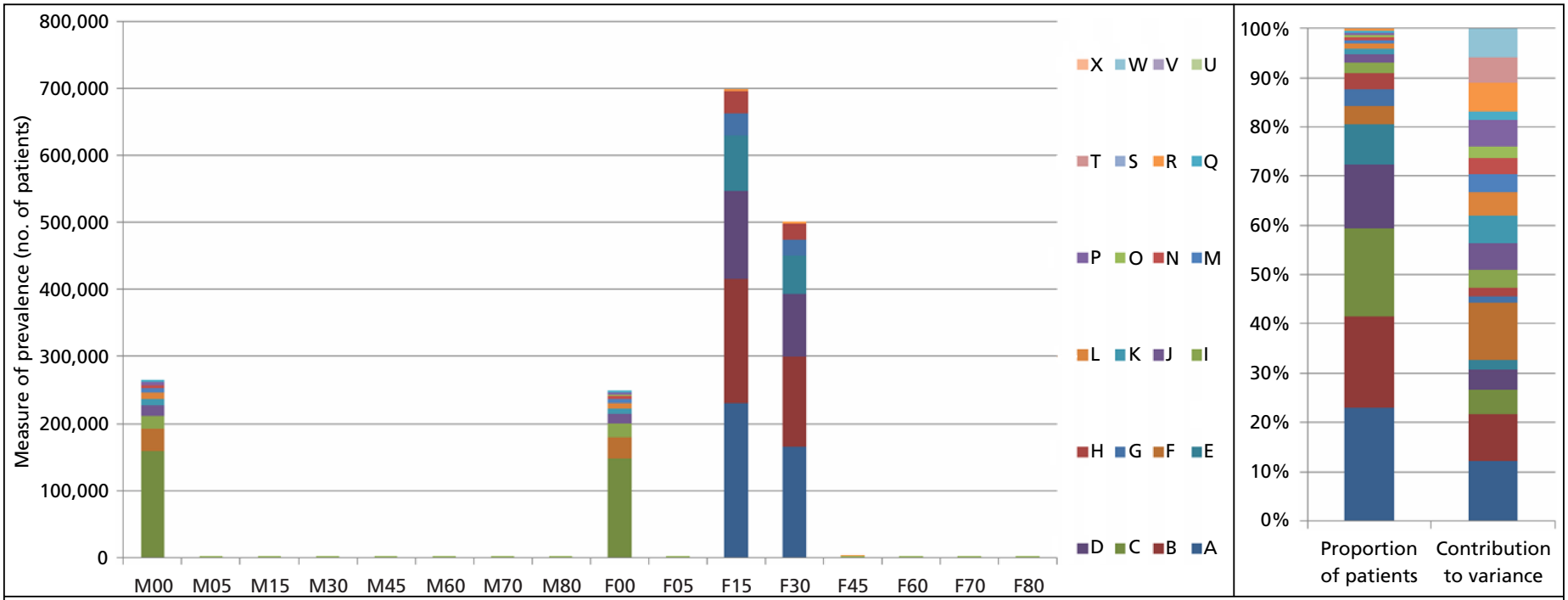
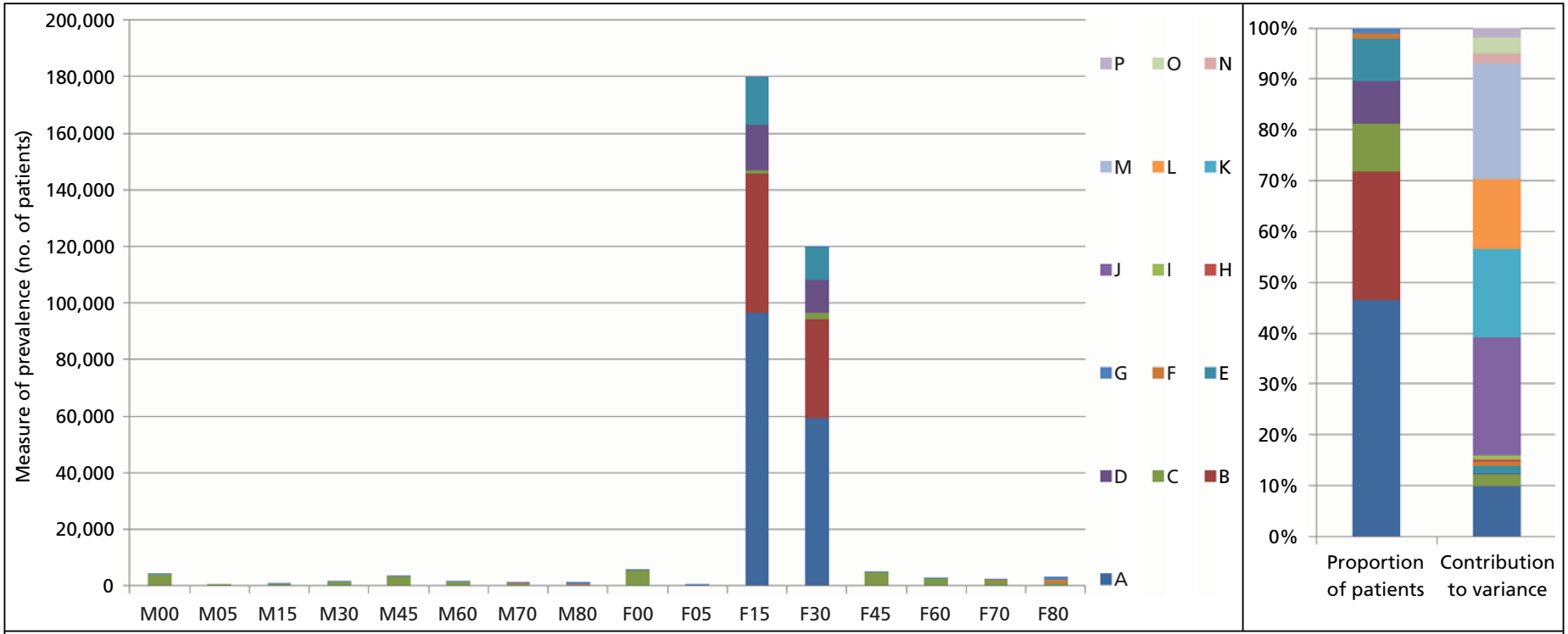


FIGURE 70 Distribution of PBC 17 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A Maternal care related to the fetus and amniotic cavity and possible delivery problems (O30–O48)
B Complications of labour and delivery (O60–O75)
C Disorders related to length of gestation and fetal growth (P05–P08)
D Other maternal disorders predominantly related to pregnancy (O20–O29)
E Delivery (O80–O84)
F Respiratory and cardiovascular disorders specific to the perinatal period (P20–P29)
G Complications predominantly related to the puerperium (O85–O92)
H Other obstetric conditions, not elsewhere classified (O95–O99)
I Birth trauma (P10–P15)
J Haemorrhagic and haematological disorders of fetus and newborn (P50–P61)
K Other disorders originating in the perinatal period (P90–P96)
L Fetus and newborn affected by maternal factors and by complications of pregnancy, labour and delivery (P00–P04)
M Infections specific to the perinatal period (P35–P39)
N Transitory endocrine and metabolic disorders specific to fetus and newborn (P70–P74)
O Other diseases of urinary system (N30–N39)
P Digestive system disorders of fetus and newborn (P75–P78)
Q Conditions involving the integument and temperature regulation of fetus and newborn (P80–P83)
R Oedema, proteinuria and hypertensive disorders in pregnancy, childbirth and the puerperium (O10–O16)
S Other bacterial diseases (A30–A49)
T Pregnancy with abortive outcome (O00–O08)
U Other bacterial diseases (A30–A49)
V Abnormal clinical and laboratory findings, not elsewhere classified (R70–R99)
W Persons encountering health services in circumstances related to reproduction (Z30–Z39)
X Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)

FIGURE 71 Distribution of PBC 18 + 19 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.



A	Complications predominantly related to the puerperium (O85–O92)	G	Disorders of skin appendages (L60–L75)	L	Other and unspecified effects of external causes (T66–T78)
B	Other obstetric conditions, not elsewhere classified (O95–O99)	H	Congenital malformations and deformations, other (Q80–Q89)	M	Complications of surgical and medical care, not elsewhere classified (T80–T88)
C	Other diseases of the digestive system (K90–K93)	I	Abnormal clinical and laboratory findings, not elsewhere classified (R70–R99)	N	Persons with potential health hazards related to family and personal history and certain conditions influencing health status (Z80–Z99)
D	Other maternal disorders predominantly related to pregnancy (O20–O29)	J	Poisoning by drugs, medicaments and biological substances (T36–T50)	O	Pregnancy with abortive outcome (O00–O08)
E	Complications of labour and delivery (O60–O75)	K	Toxic effects of substances chiefly non-medicinal as to source (T51–T65)	P	Other diseases of urinary system (N30–N39)
F	Radiation-related disorders of the skin and subcutaneous tissue (L55–L59)				

FIGURE 72 Distribution of PBC 20 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

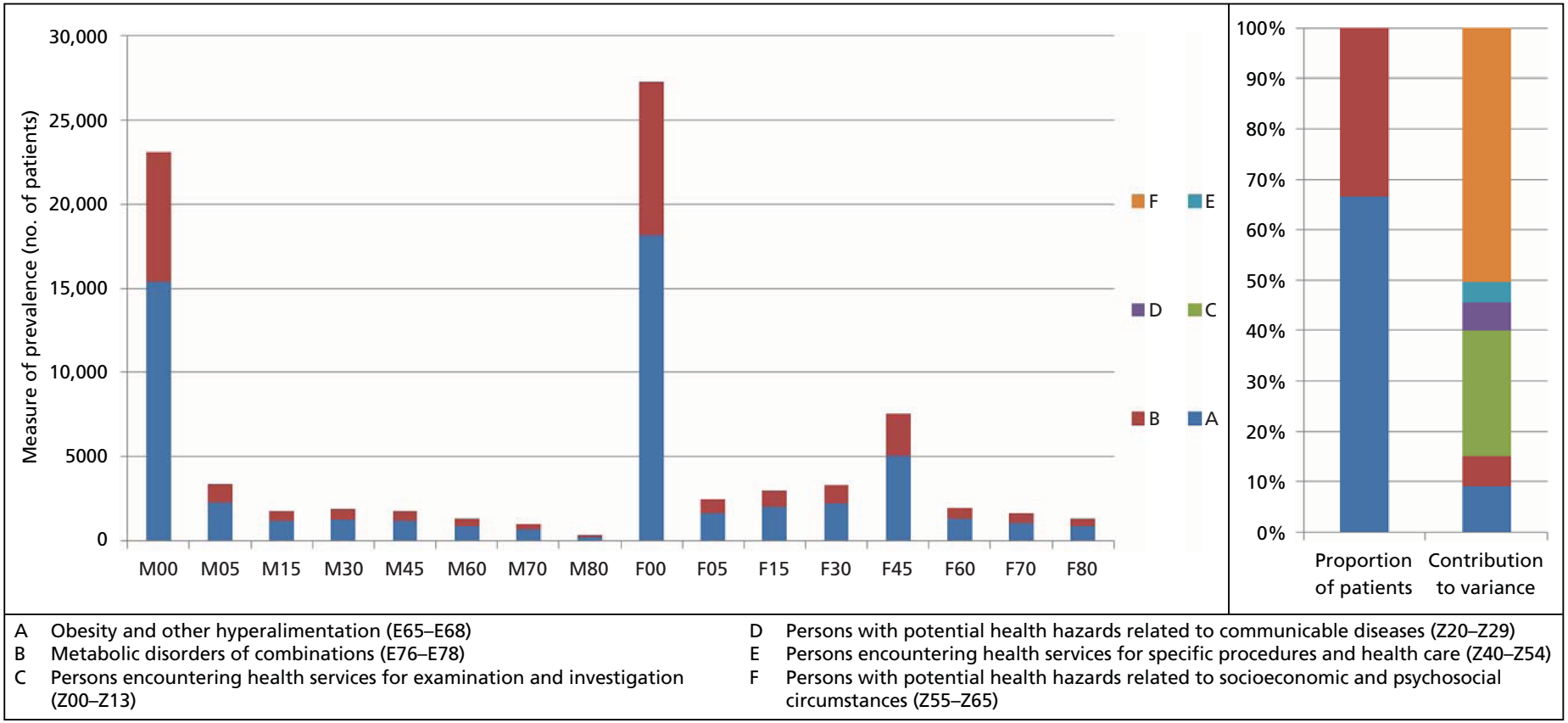


FIGURE 73 Distribution of PBC 21 prevalence by age, gender and contributing ICD-10 code alongside proportion of patients and contribution to variance of each ICD-10 code. F00, female aged 0–4 years; F05, female aged 5–9 years; F15, female aged 10–14 years; F30, female aged 15–29 years; F45, female aged 30–44 years; F60: female aged 45–59 years; F70, female aged 60–69 years; F80, female aged ≥ 70 years; M00, male aged 0–4 years; M05, male aged 5–9 years; M15, male aged 10–14 years; M30, male aged 15–29 years; M45, male aged 30–44 years; M60: male aged 45–59 years; M70, male aged 60–69 years; M80, male aged ≥ 70 years.

Addendum 2: the role of data on local NHS decisions

The role of local data in this study

The aim of this research project, noted in *Chapter 1*, is to develop and demonstrate methods for threshold estimation that make best use of routinely available NHS data. The principal focus of that methodological development, as reflected in the main body of this report, has been the use of econometric methods to exploit observed variations in spending and health outcomes between PCTs, at the programme budget level of aggregation.

However, we also aimed to investigate, as a complementary element of the project, the extent to which there may be other, more disaggregated sources of evidence on investment and disinvestment decisions made by local NHS organisations which might inform our analysis.

Specifically, we set out to (a) identify and evaluate what data might be routinely available from local NHS organisations with respect to their decisions to increase or decrease spending on specific services, and (b) consider if and how such evidence might contribute directly toward the quantitative estimates of the threshold (e.g. by providing more granular, contextual information on spending decisions that might assist in the interpretation of model estimates). For example, we wished to explore whether or not there were any routinely collected data from local NHS organisations that could tell us something about which ICD-10 codes within a given PBC might be the focus of investment and disinvestment.

The work, which was undertaken, was therefore focused on the potential use of local data *alongside* the econometric analysis, rather than their potential use as an alternative means of identifying the marginal cost of a QALY in the NHS.[76]

Sources of publicly available data on primary care trust investment and disinvestment

To help us identify possible sources of data on NHS spending decisions, we began by consulting a number of experts within the NHS, identified for us by our collaborator, Professor David Parkin (Chief Economist at NHS South East Coast). These included directors of finance, commissioning and public health. Those discussions helped direct us to a number of initiatives which involved the development of tools or evidence to inform resource allocation decisions, and helped to identify types and sources of documents published by PCTs that potentially contained relevant information on spending decisions. We then undertook a search for publicly available documents, in each case identifying what was available, and assessing its potential relevance for the purposes of this work outlined above. In evaluating each data source, the key considerations were:

(a) Whether or not the data were routinely collected: routinely-collected data are preferred, as our overarching aim is to develop a set of methods to estimate the threshold, which can be readily updated from data routinely generated by the NHS.
(b) Whether or not the data were in the public domain: published data are preferred to data that can only be obtained on request, because this would increase the cost and effort required in obtaining data from all relevant organisations.
(c) Whether or not the data were collected and reported in a systematic and consistent manner that would facilitate comparisons between PCTs, and with sufficient detail to enable us to link spending decisions to specific programme budgets or ICD-10 codes. This aspect of the work was undertaken during 2010.

The following were identified as potential sources of data.

Programme budgeting tools: quadrant analysis – Spend and Outcome Tool

Data are available for 3 years, 2006/7, 2007/8 and 2008/9 under the Spend and Outcome Tool which is available to download (from Public Health England[163]). Expenditure data are organised by PBC only, with

no lower level of disaggregation. The data show, for each PCT, the spend per head this year, the *z*-score of that spend, and the PCTs national ranking based on their *z*-score.

Outcomes data have also been captured, with different outcome measures within each PBC. Again, for each outcome there is a related *z*-score and the PCTs national ranking based on that *z*-score.

The tool enables users to see graphically how one PCT compares with others nationally, by SHA and by those PCTs similar to it by cluster (e.g. other PCTs in manufacturing towns). The quadrant analysis tool has the origin as the mean PCT for that PBC, with *z*-score for both expenditure and outcome equal to zero. The *x*-axis shows outcome, and the *y*-axis expenditure, both by *z*-score.

Although a useful tool, this source added little to the data already used in the econometric analysis, as it does not provide any additional information on the allocation of resources within PBCs.

Lists of interventions not normally funded

Most PCTs provide information about interventions not normally funded. However, these were of limited usefulness because most of the procedures listed are those that might be expected (cosmetic surgery, tattoo removal, etc.), and are not particularly informative about the marginal cost per QALY in the NHS. We did not find any information regarding whether or not any previously funded treatments had been added to these lists.

Special therapeutic and cancer committees

These are regionally based (not PCT or SHA) specialised committees that make decisions regarding spending on new cancer medicines and other special therapeutic areas. Although such decisions would be potentially of direct relevance, we were unable to find any public documentation on their processes or decision outcomes.

Quality, Innovation, Productivity and Prevention published data on efficiency savings in the NHS

Introduced in 2009, Quality, Innovation, Productivity and Prevention (QIPP) addresses the quality and productivity challenge faced by the NHS. Developed by NICE, the Cochrane Quality and Productivity topics identify areas where resources could be significantly reduced or stopped completely without reducing the quality of NHS care, releasing cash and/or resources to other areas in the NHS. Each Cochrane topic has been established from systematic reviews undertaken by reviewers at the Cochrane Collaboration.

Every month the Cochrane Collaboration informs NICE as to new or existing Cochrane reviews where they have found that the existing treatment option(s) is(are) harmful or ineffective and should not be used, or where evidence is unavailable or insufficient to support widespread use of that treatment in the NHS. NICE then completes an assessment of a Cochrane topic, to evaluate the efficiency savings that are likely against the QIPP criteria of likely ease of implementation, impact on productivity, and on the quality of care.

Savings per 100,000 patients are calculated, and then efficiency gains per PCT can be calculated. Once a topic has been accepted as best practise, users (PCTs) are encourage to submit their experience of implementing the changes, and the users achieving the best efficiency gains become QIPP examples of best practise.

The data show which procedures are considered an inefficient use of resources. However, to the extent these are based on the means of achieving the same or improved outcomes but with lower resources, they will not be revealing the marginal cost of producing a QALY in the NHS. Furthermore, there is incomplete information about the extent to which PCTs actually implement these recommendations.

NHS Right Care

This website (available at Public Health England[164]), has a section on the NHS Atlas of Variation in Health care, which seeks to reduce unwarranted variations in health care, defined as '. . . variation in the utilisation of health care services that cannot be explained by variation in patients or patients preferences', to increase value and improve quality.

It also provides an Annual Population Value Review (currently third edition) which uses PB and marginal analysis to deliver QIPP. This provides, among other things, a 10-step, structured approach for PCTs to follow to establish where investment and disinvestment decisions could be made.

Further, it provides a tool for NHS foundation trusts to improve efficiency via service line management.

Although these tools may be being used by PCTs and foundation trusts, it was not clear to what extent that was the case, and there is no routine data on their use by NHS organisations or the decisions that resulted from that.

Health Investment Network: case studies of programme budgeting and marginal analysis

The NHS network, Health Investment Network, was established to provide the access to the latest knowledge and tools to help commissioners optimise their investment and disinvestment decisions. It provides case studies of PCTs which have used PB and marginal analysis to identify efficiency gains. This includes examples of 'spend to save' decisions, for example where an initial investment (e.g. in vascular checks for men in deprived areas) could be more than outweighed by savings. Such initiatives, although important, are not useful in identifying the marginal cost per QALY in the NHS. Other case studies identify 'wish lists' (areas which PCTs prioritise for additional spending, should budgets expand) and 'hit lists' (services that might be reduced, to free up resources for more cost-effective services). These case studies provide useful selected examples, but do not provide a routine or systematic reporting of such decisions across all PCTs.

Annual operating plans and strategic commissioning plans

Primary care trusts are required to publish, each year, operating plans and strategic commissioning plans detailing their planning for the coming year, including information on the way that PCTs have made decisions concerning resource allocation. As these reports are published annually, we considered that they constituted the most promising source of data, as they are produced routinely, and cover all PCTs.

Contact details and websites were identified for all 142 PCTs. Strategic commissioning plans were obtained for an initial 70 of these. These were used to identify any information provided about programmes of care or specific services where spending was planned to be increased or decreased. Those data were extracted and recorded into a spreadsheet, along with any relevant contextual information (e.g. relating to the process by which the decision had been made).

Our review of the data from the first 70 of these showed that there was considerable variation between the documents in terms of the level of detail and specificity about the services which were the subject of changes in spending. In many cases, the services were described in terms of broad initiatives which might have related to multiple programme budgets and ICD-10 codes. There was also variation in, and occasionally a lack of clarity about, the way in which spending changes were described. For example, in some cases changes were described in terms of absolute changes in spending, in others as net changes (once estimates of offsetting savings elsewhere had been taken into account), and in others it was not stated.

Given those concerns, the data were considered unlikely to be useful to complement the econometric analysis, and the research team decided not to proceed with further data extraction for the remaining PCTs.

Conclusions

The context within which this element of the work took place may be relevant to note. Although the NHS was not subject to the budget cuts imposed on other areas of government activity in response to the financial crisis, the NHS was required to make substantial productivity improvements within its existing budgets. This gave rise to a number of initiatives in response to the 'productivity challenge' and, generally, heightened interest in the identification of ways to improve efficiency; potential areas for disinvestment; and areas for investment which were motivated by 'spend to save'. This may have made it more likely that we would observe disinvestment decisions. The NHS was also, during the course of this project, undergoing a period of restructuring. The transition from PCTs to CCGs, and the disestablishment of SHAs, may have had an effect on the availability of data and information relating to decision-making. It may also have broader implications for the availability of data in the future, given the change in administrative units.

Our review of local data sources suggested that there is very little routinely collected data on investment and disinvestment by local NHS organisations beyond the high-level aggregate data on spending by PBC which are used in the econometric analysis. More disaggregated data on spending decisions about specific services could, of course, be obtained by other means, for example by surveying PCTs, or by requesting such information from them using a freedom of information request. However, that would impose data collection costs and would need to be designed carefully to ensure that such efforts yielded complete and consistent information.

Addendum 3: characterisation of the investment and disinvestment decisions in mental health – depression and schizophrenia

Introduction

As has been highlighted in the main body of this project, it was not possible to produce an outcome equation for PBC 5, mental health problems, because no relevant mortality data was available from the NHS IC by PCT. Mental health represents a significant incidence and expenditure within the NHS. As a result, we investigated the direction of bias from the exclusion of mental health problems on our estimate of the cost-effectiveness threshold. To understand this bias we examined current investment decisions in mental health. Recent investments in treatments with ICERs above the estimated threshold would suggest that not including PBC 5 more directly in our calculation may underestimate the threshold, conversely if recent investment has ICERs below the estimated threshold it would suggest that its exclusion results in an overestimated threshold. We focussed on depression and schizophrenia because of their high prevalence and contribution to variance.

Method employed

To evaluate the direction of bias of the exclusion of PBC 5 we followed four steps to make the connection from the identification of the most significant ICD-10 codes of PBC 5 to considering the cost-effectiveness of the investment and disinvestment decisions made in the NHS around these disease areas. The strategy was as follows.

Step 1

- Identify the mental health ICD-10 codes that are most influential and suitable on which to focus our analysis.
    - Done from number of patients and contribution to variance calculations using HES.

Step 2

- Determine the medications or treatments used in the NHS to treat each of the significant ICD-10 codes.
  - There is likely to be a large crossover in the use of treatments for mental health areas, for example antipsychotics and cognitive–behavioural therapy (CBT) are both widely used.
  - We made use of the NHS Choices website coupled with clinical expertise for this identification.

Step 3

- Identify the cost-effectiveness of the current treatments and medications used in the NHS.
  - This identification will be done from a range of sources including published HTAs, published guidance, Cost-Effectiveness Analysis Registry (or Tuft's), NHS EED and MEDLINE searches.
  - This step relies heavily on the literature published; literature tends to cover historical activities many of which represent treatments of interest for this analysis. The case could be made that historical treatments that have not been evaluated have escaped evaluation due to their apparent cost-effectiveness, and are as such unlikely to be marginal activities.
  - Further difficulties arose in the identification of the relevant cost-effectiveness figure. Ideally, it would represent the cost per QALY relative to what would be performed if that activity was no longer available to the NHS.

Step 4

- Connecting the available literature on the cost-effectiveness to recent investment and disinvestment decisions made in the NHS.

Results of analysis

Step 1: identification of relevant International Classification of Disease *codes*

We first rank ICD-10 codes by prevalence and contribution to variance. Prevalence is estimated from HES data. The contribution to variance is calculated as the variance in expenditure across PCTs for each ICD-10 code compared with the total variance in expenditure across PCTs for all ICD-10 codes within PBC 5. The most prevalent ICD-10 code was for mental and behavioural disorders due to use of alcohol (F10) at 7.48% of all ICD-10 codes within PBC 5 (*Table 193*). The ICD-10 code with the greatest contribution to variance was for schizophrenia (F20) with 45.16% (*Table 194*).

Depression (F32) and (F33) and schizophrenia (F20) have been chosen as the focus of our evaluation as they represent two of the largest mental health ICD-10 codes in terms of proportion of patients as well as proportion of variance in expenditure, as shown in *Tables 193* and *194*. In addition, they represent ICD-10 codes that involve interventions by the NHS that can be more clearly defined (in contrast to, for example, unspecified dementia and mental and behavioural disorders due to the use of alcohol).[ad]

Step 2: determination of treatment employed

Table 195 provided an overview of the main treatments for depression and schizophrenia. This list of treatments was identified using the NHS Choices website[165] as well as discussion with our clinical representative for each of the respective illnesses. This list was used to inform a literature search of cost-effectiveness publications.

TABLE 193 Table showing ranking of mental health ICD-10 codes by prevalence from HES

ICD-10 code	Description	% of mental health prevalence	Contribution to variance
F10	Mental and behavioural disorders due to use of alcohol	27.84	9.70
F20	**Schizophrenia**	**10.01**	**45.16**
F32	**Depressive episode**	**9.96**	**6.91**
F31	Bipolar affective disorder	6.19	6.38
F41	Other anxiety disorders	4.92	0.26
F60	Specific personality disorders	4.33	14.11
F03	Unspecified dementia	3.93	3.29
F01	Vascular dementia	3.32	1.58
G30	Alzheimer's disease	3.30	0.84
F33	**Recurrent depressive disorder**	**2.83**	**3.68**

TABLE 194 Table showing ranking of mental health ICD-10 codes by contribution to variance

ICD-10 code	Description	% of mental health prevalence	Contribution to variance
F20	Schizophrenia	10.01	45.16
F60	Specific personality disorders	4.33	14.11
F10	Mental and behavioural disorders due to use of alcohol	27.84	9.70
F32	Depressive episode	9.96	6.91
F31	Bipolar affective disorder	6.19	6.38
F33	Recurrent depressive disorder	2.83	3.68
F03	Unspecified dementia	3.93	3.29
F01	Vascular dementia	3.32	1.58
G30	Alzheimer's disease	3.30	0.84
F41	Other anxiety disorders	4.92	0.26

TABLE 195 Table showing treatments for schizophrenia and depression in the NHS

ICD-10 code	Disease	Treatment
F20	Schizophrenia	1. Typical antipsychotics 2. Atypical antipsychotics 3. CBT 4. Crisis resolution teams
F32 and F33	Depressive episode and recurrent depressive episode	1. CBT 2. Interpersonal therapy 3. SSRIs 4. SNRIs 5. TCAs 6. MAOIs 7. Lithium 8. Electroconvulsive therapy

MAOI, monoamine oxidase inhibitor; SNRI, serotonin–norepinephrine reuptake inhibitor; SSRI, selective serotonin reuptake inhibitor; TCA, tricyclic antidepressant.

Step 3: evaluation of the relevant cost-effectiveness literature

Using the treatment categories identified in step 2 of this work, a systematic search was conducted to attempt to identify the range of literature on the cost-effectiveness of current NHS treatment of schizophrenia and depression. For both illnesses five online databases were searched: the Cost-Effectiveness Analysis Registry of the Tufts Medical Centre, NHS EED run by the Centre for Reviews and Dissemination at the University of York, MEDLINE, the NICE online database of Technical Appraisals and Clinical Guidelines, as well as NIHR's Health Technology Assessments. All searches were conducted on the 19 October 2011.

The search strategies employed to search for relevant cost-effectiveness literature and details of the results can be found in the search strategy section at the end of this addendum. For schizophrenia, this approach identified 61 unique publications, five of which were deemed to be of broad relevance to this analysis. For depression, 65 publications were discovered, 10 of which were relevant. A paper of relevance to our analysis of mental health was deemed to be so if it presented cost-effectiveness results (in the form of a cost per QALY ICER) of a comparison of at least two of the treatments for either schizophrenia or depression identified in *Analysis of 2006/7 expenditure and 2006/7/8 mortality data*. These results could be from a de novo analysis or from a systematic review of the relevant literature.

Table 196 reports the cost-effectiveness results of antipsychotics for schizophrenia as first-line treatments. The NICE Clinical Guidelines for schizophrenia (CG82)[166] demonstrate that the differences in costs and effects of the first- and second-generation treatments described are very similar with ICERs comparing each with no treatment ranging from £21,517 to £23,237 per QALY. Comparisons to active treatments result in ICERs of £5156 to £33,240 per QALY.[167,168]

The CG82 results are similar to the first-line treatment results from Bagnall *et al.*,[169] shown in *Table 197*. The cost-effectiveness of antipsychotics compared with no treatment as second, third or final therapy are < £20,000 per QALY.

TABLE 196 Table showing cost-effectiveness studies of antipsychotics for schizophrenia

Study	Treatment	Comparator	Cost (£)	QALYs	ICER (£/QALY)
NICE CG82[166]	Zotepine (Zoleptil®, Movianto) (second)	No treatment	139,170	6.468	21,517
	Paliperidone (Invega®, Johnson & Johnson) (second)	No treatment	142,173	6.427	22,121
	Olanzapine (Zyprexa®, Eli Lilly) (second)	No treatment	141,212	6.42	21,996
	Risperidone (Risperdal®, Johnson & Johnson) (second)	No treatment	149,112	6.417	23,237
	Haloperidol (Haldol®, McNeil Laboratories) (first)	No treatment	143,406	6.413	22,362
	Aripiprazole (Abilify®, Bristol-Myers Squibb) (second)	No treatment	145,697	6.400	22,765
	Amisulpride (Arnival®, Sanofi-Aventis) (second)	No treatment	147,920	6.392	23,141
Knapp *et al.* 2008[167]	Olanzapine (second)	Other antipsychotics			5156
Davies *et al.* 2008[168]	Clozapine (Clozaril®, Novartis) (second)	Other second-generation antipsychotics			33,240
	Aripiprazole then risperidone	Risperidone then olanzapine			9440

TABLE 197 Table showing cost-effectiveness studies of antipsychotics for schizophrenia

Bagnall *et al.* 2003[169]				
	Line of treatment: ICER (£/QALY)			
Antipsychotic	First	Second	Third	Final
Chlorpromazine (Largactil®, Sanofi-Aventis) (first)	21,989	15,185	15,419	15,303
Haloperidol (first)	24,069	17,177	17,211	17,022
Clozapine (second)	24,500	17,595	17,577	17,402
Olanzapine (second)	25,719	18,869	18,808	18,865
Quetiapine (Seroquel®, AstraZeneca) (second)	26,316	19,090	18,751	19,096
Zotepine (second)	22,769	16,350	16,360	16,400
Risperidone (second)	22,255	15,596	15,599	15,700
Ziprasidone (Geodon®, Pfizer) (second)	21,935	15,192	15,191	15,224
Amisulpride (second)	23,174	15,941	15,945	15,962
Sertindole (Serdolect®, Lundbeck) (atypical)	23,181	16,297	16,308	16,354

Only one study reported the cost-effectiveness of a psychological or social intervention for schizophrenia. Barton *et al.*[170] conducted a randomised trial to estimate the clinical effectiveness and cost-effectiveness of social recovery orientated cognitive–behavioural therapy (SRCBT) against case management alone for people recently diagnosed with psychosis. SRCBT consisted of three stages of social recovery combined with CBT techniques including vocational case management. SRCBT was found to have an ICER of £18,844 per QALY compared with case management. However, it is not clear that all forms of CBT are well represented by this one study or that these results relate well to schizophrenia as this study was for the use of SRCBT for psychosis disorders in general.

Table 198 reports the cost-effectiveness results of publications identified in the systematic search of drug treatments for depression in the NHS. As was highlighted in *Table 195*, a range of drug treatments are available for depression, broadly falling into five categories: selective serotonin reuptake inhibitors (SSRIs), serotonin–norepinephrine reuptake inhibitors (SNRIs), tricyclic antidepressants (TCAs), monoamine oxidase inhibitors and lithium.

The NICE guideline CG90 tested the cost-effectiveness of numerous treatments for moderate and severe depression. It was found that across all the treatments tested the mean QALYs for moderate depression had a range of 0.053 and severe depression had a range of 0.065. The costs had a range of £408 for moderate and £396 for severe depression. The results suggest that mirtazapine has the lowest ICER for both moderate and severe depression. If mirtazapine is not a suitable treatment option than escitalopram or sertraline is preferred because escitalopram dominates venlafaxine and sertraline dominates the remaining antidepressants. The ICERs of escitalopram versus sertraline are £32,987 per QALY for moderate depression and £27,172 per QALY for severe. The authors thus suggest that according to these results escitalopram should be considered when mirtazapine and sertraline are not suitable. Other ICERs reported in CG90 can be found in *Table 198*. CG90 states that the economic evidence had limitations and these comparisons were considered insufficient to make specific recommendations for treatments.

Incremental cost-effectiveness ratios in other studies range from £2172 to £20,600 per QALY, with TCA alone being dominated by lofepramine (TCA) in two cases and fluoxetine (SSRI) being dominated by amitriptyline (TCA).

TABLE 198 Table showing cost-effectiveness of drug treatments for depression

Study	Treatment	Comparator	Incremental cost	Incremental QALY (£)	ICER (£/QALY)
NICE CG90[171]	Combined SSRI and CBT (severe depression)	SSRI alone			5558
	Duloxetine (Cymbalta®, Eli Lilly) (SNRI)	SSRI			6300
	Duloxetine (SNRI)	Mirtazapine (Avanza®, Organon) (TCA)			2400
	Duloxetine (SNRI)	Venlafaxine (Effexor®, Pfizer) (SNRI)			Dominates
	Escitalopram (Lexapro®, Forest Laboratories) (moderate depression) (SSRI)	Sertraline (Zoloft®, Pfizer) (SSRI)			32,987
	Escitalopram (severe depression) (SSRI)	Sertraline (SSRI)			27,172
Lenox-Smith *et al.* 2009[172]	Venlafaxine (major depression) (SNRI)	SSRI			20,600
	Fluoxetine (Prozac®, Eli Lilly) (SSRI)	Amitriptyline (Elavil®, Densa) (TCA)			Dominated
Kendrick *et al.* 2006[173]	SSRI	TCA			2692
	TCA	Lofepramine (Gamanil®, GlaxoSmithKline) (TCA)			Dominated
	SSRI	Lofepramine (TCA)			5686
Hatziandreu *et al.* 1994[174]	Sertraline (SSRI)	Dothiepin (TCA)			2172
Peveler *et al.* 2005[175]	SSRI	Lofepramine (TCA)	0.035	199	5686
	TCA	Lofepramine (TCA)	−0.004	93	Dominated
	SSRI	TCA	0.039	105	2692
Kendrick *et al.* 2009[176]	SSRI + standard care	Standard care			14,854

Table 199 provides the results of the combination therapies for moderate and severe depression presented in CG90[171] and Simon *et al.*[177] These studies considered the impact of combined SSRI and CBT compared with SSRI alone. Both of these studies find combined CBT and antidepressant to have ICERs of < £8000 per QALY.

In addition *Table 199* provides results of analyses of computerised CBT compared with treatment as usual or relaxation. The results generally find CBT and computerised CBT to be highly cost-effective, with the exception of Behavioral Therapy Steps[179] all ICERs are found to be < £18,000 per QALY.

TABLE 199 Table showing cost-effectiveness of psychological and social intervention for depression

Study	Treatment	Comparator	Incremental cost (£)	Incremental QALY	ICER (£/QALY)
NICE CG90[171]	Combined SSRI and CBT (moderate depression)	SSRI alone			7052
	Combined SSRI and CBT (severe depression)	SSRI alone			5558
Simon *et al.* 2006[177]	CBT + antidepressants in severe depression	Fluoxetine			5777
	CBT + antidepressants in moderate depression	Fluoxetine			14,540
Kaltenthaler *et al.* 2002[178]	BtB computerised CBT	TAU			1209–7692
Kaltenthaler *et al.* 2006[179]	BtB	TAU	147	0.08	1801
	Cope computerised CBT	TAU	193	0.03	7139
	Overcoming depression computerised CBT	TAU	64	0.01	5391
	FearFighter computerised CBT	Relaxation CBT	138	0.058	2380
	Therapist lead CBT	Relaxation	194	0.011	17,604
	Behavioural therapy steps computerised CBT	Relaxation	360	–0.01	Dominated
Hollinghurst *et al.* 2010[180]	Online computerised CBT	TAU			17,173

BtB, Beat the Blues; TAU, treatment as usual.

Step 4: connection to investment and disinvestment decisions

In this section we discuss the investment and disinvestment decisions made considering the cost-effectiveness information in the previous section. If we believe that decision-makers will invest in treatments below their cost-effectiveness threshold and disinvest in treatments above this threshold then by considering the ICERs of treatments subject to investment and disinvestment we can create a range for their cost-effectiveness threshold. This approach and its role in the consideration of a cost-effectiveness threshold has been previously discussed by Appleby *et al.*[49] With a view of the cost-effectiveness threshold within PBC 5 we consider how its exclusion from our calculation of the threshold might influence our results.

To identify the broad areas of investment in the disease areas we make use of recent NICE guidance documents. Although NICE clinical guidance does not definitively represent observed shifts in practice and are often not well implemented in mental health trusts[181] it can help to inform our evaluation. NICE guidance does not identify areas where disinvestment should occur within a disease; as a result, we have consulted experts in the respective fields to gain an understanding of any significant recent disinvestment decisions. For schizophrenia we were provided expert opinion by Professor Tim Kendall (Centre for Psychological Services Research, University of Sheffield) and for depression by Professor Simon Gilbody (Health Sciences, University of York).

For both schizophrenia and depression we will briefly discuss the areas of investment and disinvestment in two care categories: (i) drug treatments, and (ii) psychological and social interventions.

Results of step 4 for schizophrenia

Analysis of drug treatment

Antipsychotics used for the treatment of schizophrenia can be broadly identified as first or second generation (typical and atypical antipsychotics). To a certain extent there is still a debate over the relative strengths and weaknesses of each,[182] and the significance of the adverse events associated with the second generation may still not be fully understood (such as the impact on new-onset type 2 diabetes[183]). However, our clinical experts indicated that clinicians were largely concerned with the adverse effects associated with the second-generation drugs, and the increasing evidence questioning the relative efficacy, such as Rosenheck *et al.*[182] who suggests that the first-generation drugs in many cases are just as effective. Recent NICE guidance leaves the choice of first- or second-generation drugs to the clinician to decide.[166]

When considering the impact on our estimate of the threshold of the possible shift to first- from second-generation antipsychotics we must attempt to generalise about the relative cost-effectiveness of the two. Clearly this is difficult as each generation represents many different drugs. However, from CG82 the costs and benefits of the mainstream antipsychotics are broadly similar *Table 196*. This would suggest that a shift away from the second generation back towards the first would have little impact on the overall threshold as the costs and benefits associated with each are very similar.

Olanzapine came off patent in the third quarter of 2011.[184] Olanzapine and similar second-generation antipsychotics are associated with a cost of around £30M a year,[ae] clearly the introduction of generics to the market would significantly reduce this cost and thus increases the cost-effectiveness of these drugs. Although this shift does not fall within the years of our analysis, it will have a significant impact on the future value of the cost-effectiveness threshold.

The other significant area of debate, as identified by our clinician, is the role of the antipsychotic clozapine. It has often been viewed as the most effective antipsychotic drug for schizophrenia, however, the antipsychotic clozapine has been connected with some severe adverse events (such as myocarditis,[185] agranulocytosis[186] and central nervous system depression). This has led to the NICE guidelines advising clozapine only if an array of other antipsychotics has failed.[166] Although clozapine is highly clinically effective it is associated with a higher overall cost (a significant proportion due to the associated adverse events). As is shown in *Table 196*, Davies *et al.*[168] show clozapine to have an ICER of £33,240 when compared with other second-generation antipsychotics. Disinvestment of clozapine suggests that the threshold is < £33,240 per QALY. However, current investment in other first-line antipsychotics suggests that the threshold in mental health is > £23,237 per QALY.

Analysis of psychological and social intervention

In this section we discuss all non-drug-related interventions for schizophrenia. The NICE guidelines[166] outline the provision of CBT, arts therapy and family interventions to treat schizophrenia; however, efficacy of these interventions is disputed[187] and little is known about their cost-effectiveness. The systematic review only yielded one paper that was relevant to our analysis, as is shown in *Table 200*. The Barton *et al.*[170] study found that SRCBT had an ICER of < £20,000 per QALY relative to case management. However, as mentioned previously, this study may not represent all forms of CBT for schizophrenia.

TABLE 200 Table showing cost-effectiveness of psychological/social interventions for schizophrenia

Study	Treatment	Comparator	ICER (£/QALY)
Barton *et al.* 2009[170]	SRCBT	Case management	18,844

Our clinical advisors informed us that CBT provision varies significantly across PCTs and therefore represents an intervention likely to be subject to investment and disinvestment at the margin. The variation in CBT provision (and indeed other psychosocial/social interventions) is largely a result of the poor support for its efficacy and significant initial cost.

Other interventions of relevance to this investigation include art therapies and family interventions. As with CBT there is a significant variation in the provision of family interventions. No information on its cost-effectiveness was found from our search. Art therapies include music therapy; art therapy; and body movement or dance therapy. Our clinical advisors have highlighted increasing investigations into arts therapy, including the 'Matisse trial',[188] publications around which have shown that art therapy as adjunctive therapy had little benefit over a comparator activity or treatment as usual.[187] No information on its cost-effectiveness was found from our search.

Early interventions in schizophrenia, which aims to identify and treat early symptoms associated with schizophrenia, have been a significant area of investment over recent years in the NHS. Although we were unable to identify any relevant cost-effectiveness literature around early interventions in schizophrenia it is generally expected that these represent cost-effective interventions over the long term.[af]

Although the lack of cost-effectiveness literature clearly limits the potential to directly associate these interventions with the wider cost-effectiveness threshold it is widely accepted that many social interventions for schizophrenia (specifically around CBT and family interventions) are cost-saving for the NHS,[af] as they reduce hospitalisation by reducing emergency hospital access and relapse rates that are high in schizophrenia representing the majority of related hospitalisations.[189]

Investment in CBT with an expected ICER of £18,844 per QALY suggests that the threshold for mental health treatments is above this value.

Results of step 4 for depression

As *Table 195* shows, depression is associated with a wider range of treatment than schizophrenia, specifically a wider range of drug treatments are available. As with the schizophrenia section of this addendum we will deal with the treatments under the two categories of drug treatments and psychological/social interventions. Electroconvulsive therapy, which is included in the treatment options available in the NHS as shown in *Table 195*, is excluded from this analysis based on expert opinion on the grounds of it being a very rarely used but extreme treatment that is not likely to be further subject to substantial investment or disinvestment, so is not relevant for our analysis.

Recent NICE clinical guidance[171] highlights a range of key priorities for implementation. As with schizophrenia there is no guarantee that these are the areas of investment in depression care but it represents a suitable outline of the areas of interest. Several areas are highlighted:

- early identification and diagnosis
- low intensity psychological interventions (CBT, computerised CBT and group physical activity) for persistent subthreshold depressive symptoms or mild to moderate depression
- reduced routine use of antidepressants for subthreshold depressive symptoms or mild depression
- combination therapies (antidepressant and psychological) for moderate or severe depression
- extension of therapy (antidepressant and psychological) beyond remission to reduce relapse
- SSRIs are presented as the preferred type of antidepressant due to their equivalent efficacy and favourable risk–benefit ratio.

These are the areas of investment that our analysis will focus on.

Analysis of drug treatment

Our clinical advisors reported that the current area of activity in antidepressants is the creation of drugs such as escitalopram (a SSRI) and venlafaxine (a SNRI) that are relatively similar to generic treatments currently in the market. As these new drugs are covered by patents they are relatively expensive. *Table 198* reports the results on the cost-effectiveness of these two drugs from NICE CG90[171] as well as Lenox-Smith *et al.*[172] In both reports the drugs are compared with alternative SSRIs in moderate and severe depression. In both cases the newer SSRIs were approved by NICE with an ICER for escitalopram of £32,987 per QALY and for venlafaxine of £20,600 per QALY. If mirtazapine and sertraline are not suitable then the ICER of escitalopram for moderate depression is £5357 per QALY compared with citalopram. Although evidence was not available on whether or not clinicians were making use of these newer SSRIs, an investment in them away from alternative SSRIs may represent an increase in the cost-effectiveness threshold due to the relatively high ICERs reported in the two studies. However, the cost-effectiveness of each depends on what they displace and ICERs may be lower if the more cost-effective treatments have failed.

Investment decisions in the NHS for antidepressants are likely to represent changes in the type of antidepressant being prescribed rather than a shift from no treatment to treatment. The majority of trials discovered by systematic review given in *Table 198* show that although the ICER of SSRIs compared with TCAs is very low,[175] this is largely driven by very small gains in QALYs but for a similarly small increase in cost. As a result any observed investment in SSRIs away from TCAs is likely to lead to a small decrease in an observed threshold for the NHS.

Analysis of psychological and social intervention

The NICE guidelines reported in CG90 place a lot of focus on the provision of psychological interventions such as CBT (and computerised CBT) over antipsychotics wherever possible. *Table 199* provides the results of the combination therapies for moderate and severe depression presented in CG90[171] and Simon *et al.*[177] These considered the impact of combined SSRI and CBT compared with SSRI alone and concluded that combined therapies in both populations had ICERs of < £15,000 per QALY. According to our clinicians, this is an area that is likely to have had significant investment in recent years.

The two HTA reports in *Table 199*[178,179] provide a good analysis of the cost-effectiveness of computerised CBT compared with treatment as usual. They show that the computerised CBTs investigated have ICER of < £8000 per QALY relative to TAU. Further analyses investigated different kinds of computerised CBT and found that compared with relaxation, CBT ICERs ranged from £2380 per QALY to dominated. Hollinghurst *et al.*[180] report that two CBT interventions compared to TAU had ICERs of £17,173.

As NICE guidelines encourage the use of CBT and our clinical experts believe this has been an area of increased investment, this review suggests that the threshold in mental health is > £17,173 per QALY.

Conclusion

There is very little accessible data on the investment and disinvestment decisions in specific areas of mental health and so we relied on the opinions of clinical experts. The NHS IC has some information on prescriptions of mental health treatments; however, it was not clear for which diseases these treatments were being used or for which line of therapy. As a result, these data were not included in our analysis as it was decided they may not represent the investment and disinvestment decisions that we were seeking to identify.

Most treatments reviewed had an ICER of < £24,000 per QALY. Two treatments had higher ICERs. Clozapine for the first-line treatment of schizophrenia was found to have an ICER of £33,240 per QALY compared to other second-generation antipsychotics. NICE's recommendation to use clozapine only as a last-line treatment suggests that the threshold is < £33,240 per QALY. Escitalopram for moderate depression has been recommended by NICE and was reported to have an ICER of £32,987 per QALY compared with seratraline.

Conclusions on the threshold from this finding are unclear. The cost-effectiveness of escitalopram in the NHS will depend on its use. If it is used rather than seratraline then the threshold may be over £32,987, but if it is used as third-line therapy than according to CG90 its use is less costly and more effective than the next best options.

How well the actual threshold reflects the ICERs reported above depends on how well clinical practice matches the clinical guidelines (i.e. whether or not the more cost-effective treatments are being used first).

Search strategies

Search strategy for schizophrenia

Cost-Effectiveness Analysis Registry search

Six keywords associated with the entire schizophrenia, schizotypal and delusional disorders. ICD-10 subchapters were searched for in the CEA Registry, these were: schizophrenia, schizotypal, delusional, psychotic, schizoaffective and psychosis. A search for any of these keywords in the registry yielded 18 different papers at the time of searching, with five of these being deemed suitable for our investigation (Barton *et al.*,[170] Davies *et al.*,[168] Jarbrink *et al.*,[190] Knapp *et al.*[167] and Davies *et al.*[191]).

NHS Economic Evaluation Database search

A single relatively simple search strategy was defined to investigate NHS EED, this was as follows:

((Schizophrenia) AND (cost effectiveness):TI) and Economic evaluation:ZDT and Abstract:ZPS

This result strategy yielded 28 hits, only one of which was both relevant to our search and not discovered in the CEA Registry search (Rosenheck *et al.*).[182]

MEDLINE search

MEDLINE was searched using the strategy:

cost benefit analysis and (schizophrenia or schizotypal personality disorder or delusions) and Great britain(MeSH)

This strategy yielded 13 hits, none of which were both relevant and had not been previously identified through the CEA Registry or NHS EED searches.

National Institute for Health and Care Excellence technology appraisals and clinical guidelines

The NICE online database of published mental health-related technology appraisals and clinical guidelines (www.nice.org.uk/guidance/index.jsp?action=byTopic&o=7281) was searched for schizophrenia-related publications. Only one was found to fulfil our criteria for schizophrenia: CG82.[192]

National Institute for Health Research's Health Technology Assessments

Finally the NIHR's database of published HTAs was searched. This activity discovered one additional relevant publication: HTA 00/20/01 – Bagnall *et al.*[169]

Search strategy for depression

Cost-Effectiveness Analysis Registry search

Two keywords were searched on the CEA Registry, they were: depression and depressive. These keywords yielded 17 papers, five of which were deemed relevant for our purposes (Hollinghurst *et al.*,[180] Lenox-Smith *et al.*,[172] Kendrick *et al.*,[173] Simon *et al.*[177] and Hatzinandreu *et al.*[174]).

NHS Economic Evaluation Database search

A search similar in structure to the search for schizophrenia papers was conducted in the NHS EED:

((depressive OR depression):TI AND (cost-effectiveness):TI) and Economic evaluation:ZDT and Abstract:ZPS) IN NHSEED

This yielded 43 hits, none of which were both relevant and previously undiscovered by the CEA registry search. Due to the complete nature of the CEA Registry and NHS EED searches, as well as time constraints on the systematic review, a MEDLINE search was not conducted as it was decided it would not provide sufficient added value.

National Institute for Health and Care Excellence technology appraisals and clinical guidelines

Searching the NICE database of technology appraisals and clinical guidelines yielded one publication deemed relevant to the analysis: CG90 – depression in adults.[193]

National Institute for Health Research's Health Technology Assessments

A search of the NIHR's online database of published HTAs yielded four relevant publications:

HTA 01/23/01– Kaltenthaler *et al.*[178]

HTA 04/01/01– Kaltenthaler *et al.*[179]

HTA 96/61/11– Peveler *et al.*[175]

HTA 01/70/05 – Kendrick *et al.*[176]

Addendum 4: what type of health is forgone by the approval of a new technology?

The methods of analysis described in this work can identify not only how many QALYs are likely to be forgone across the NHS as a consequence of approving a technology which imposes incremental costs on the NHS, it can also indicate where those QALYs are likely to be forgone and how they are made up [i.e. the additional deaths, life-years lost (unadjusted and adjusted for QoL) and the QoL impacts on those with disease]. Based on the 2008 central estimate of the cost per QALY threshold, we will exemplify within this addendum the likely health displaced elsewhere in the NHS as a consequence of approving a new technology.

The example of ranibizumab for diabetic macular oedema

In 2011, NICE considered whether or not ranibizumab for the treatment of diabetic macular oedema in patients with central retinal thickness ≥ 400 micrometres should be approved for widespread use in the NHS (TA237[105]). Initially, this technology was rejected by NICE on the grounds that, at its current price, it would be unlikely to be cost-effective. In 2012, however, a rapid review of TA237[106] approved ranibizumab if use was restricted to the most cost-effective subgroup (those with central retinal thickness ≥ 400 micrometres) and after a PAS for this subgroup of patients was offered (details of the PAS which provides a discount to the NHS is commercial in confidence). The committee concluded that the most plausible ICER for the subgroup of people with thicker retinas was likely to be higher than the manufacturer's estimate (of £13,322 per QALY), but would be < £25,000 per QALY gained.[106]

The appraisal and guidance documents[106] provide the information required to estimate the additional NHS costs of treating this subgroup of patients each year. The original manufacturer submission presented an estimate of the numbers of patients in the NHS eligible to receive ranibizumab, based on its licensed

indication.[107] These estimates are presented in *Table 201*. In the first year of implementation, up to 44,000 NHS patients would be eligible for treatment with ranibizumab based on its licensed indication. No consideration is made as to the size of the subpopulation approved for treatment; however, the RESTORE trial (that informs the submission) found approximately half of the participants in the study to be in this subpopulation [114 of 217 (52.5%)].[105] The subgroup of patients where ranibizumab was ultimately approved is thus likely to be approximately 23,000 in the first year after approval.

The incremental costs associated with the new treatment (compared with laser monotherapy) in the initial submission (TA237) were £3506 per patient (*Table 202*).[107] Given estimates reported in the rapid review are not available (commercial in confidence), we will use this estimate of incremental costs for the subpopulation of interest. These data suggest that the approval of ranibizumab in this subgroup at the original appraisal in 2011 (i.e. without a PAS) would impose just over £80M of additional NHS costs for treating the eligible population each year.

With introduction of the PAS, it is likely that a simple discount on the acquisition price of the new technology has been approved by the Department of Health.[106] Given the scale of the discount is not available (commercial in confidence), we assumed that this discount would reduce incremental costs by 30% (to £2454 per patient). After such a PAS, the approval of ranibizumab in this subgroup would impose just £56M (rather than £80M) of additional NHS costs for treating the eligible population in the first year.

What type of health is forgone by approval of a new technology?

Based on the 2008 central estimate of the cost per QALY threshold (£12,936 in *Table 30*), the approval of ranibizumab without a PAS would have been likely to displace 6184 QALYs elsewhere in the NHS. However, the analysis which underpins the threshold estimate can also be used to identify where the additional NHS cost of £80M are likely to impact and where and what type of health effects are likely to be forgone. This is illustrated in *Table 203*.

How the additional NHS cost of £80M will tend to affect spending in each of the 23 PBCs [see *Table 203*, column (1)] will be based on the estimated expenditure elasticities and total PBC expenditure (see *Table 157*). In calculations of the threshold, the inputs above (expenditure elasticities and total expenditure) allow

TABLE 201 Estimated size of the NHS population eligible for ranibizumab[107]

Licensed indication	2011	2012	2013	2014	2015
Prevalent cases	43,847	0	0	0	0
Incident cases	0	5481	5481	5481	5481
Total eligible number of patients	43,847	49,328	54,809	60,290	65,771
Subpopulation approved for treatment by NICE					
Prevalent cases	23,020	0	0	0	0
Incident cases	0	2878	2878	2878	2878
Total eligible number of patients	23,020	25,897	28,775	31,652	34,530

TABLE 202 Estimated total budget impact of ranibizumab

	2011	2012	2013	2014	2015
Total eligible number of patients	23,020	25,897	28,775	31,652	34,530
Total cost, without PAS (£)	80,708,120	90,794,882	100,885,150	110,971,912	121,062,180
Total cost, 30% lower incremental costs (£)	56,495,684	63,556,417	70,619,605	77,680,338	84,743,526

TABLE 203 Heath forgone across PBCs due to the approval of ranibizumab (£80M budget impact)

PBC		(1) Change in spend (£M)	(2) Additional deaths	(3) Life-years foregone	QALYs foregone		
					(4) Total QALYs forgone	(5) Due to premature death	(6) QoL effects
2	Cancer	3.58	30	300	211	195	16
10	Circulatory problems	6.07	182	928	863	590	273
11	Respiratory problems	3.67	107	129	1835	80	1754
13	Gastrointestinal	2.56	21	197	351	129	222
All big four programmes		*16*	*340*	*1554*	*3259*	*995*	*2265*
1	Infectious diseases	2.61	6	43	125	29	97
4	Endocrine problems	1.51	5	40	485	26	459
7	Neurological problems	4.78	10	52	873	34	838
17	Genitourinary problems	3.71	18	26	85	17	68
16	Trauma and injuries	6.16	0	0	0	0	0
18 + 19	Maternity and neonates	5.46	0	3	2	1	1
11 PBCs		*40*	*389*	*1717*	*4828*	*1101*	3727
3	Disorders of blood	1.65	3	13	175	9	166
5	Mental health disorders	14.29	23	103	762	67	696
6	Learning disability	0.83	0	2	6	1	4
8	Problems of vision	1.55	0	2	34	1	33
9	Problems of hearing	0.70	0	1	112	1	111
12	Dental problems	2.31	0	0	54	0	54

continued

TABLE 203 Heath forgone across PBCs due to the approval of ranibizumab (£80M budget impact) (*continued*)

PBC		(1) Change in spend (£M)	(2) Additional deaths	(3) Life-years foregone	QALYs foregone		
					(4) Total QALYs forgone	(5) Due to premature death	(6) QoL effects
14	Skin	1.57	2	9	16	6	10
15	Musculoskeletal system	2.90	3	14	186	9	176
20	Poisoning and adverse events	0.74	0	2	7	1	5
21	Healthy individuals	2.83	0	1	5	1	5
22	Social care needs	2.40	0	0	0	0	0
23	Other	8.11	0	0	0	0	0
All 23 PBCs		*80*	*411*	*1864*	*6184*	*1197*	*4987*

TABLE 204 Heath forgone across specific PBCs and groups of ICD-10 codes due to the approval of ranibizumab (£80M budget impact)

Total change in spend analysed = £80M	(1) Change in spend (£M)	(2) Life-years foregone	QALYs foregone		
			(3) Total QALYs forgone	(4) Due to premature death	(5) QoL effects
Overall	80	1864	6184	1197	4987
PBC specific					
PBC 2 (cancer)	3.58	300	211	195	16
Malignant neoplasms, digestive organs (C15–C26)		81	56	53	3
Malignant neoplasms, respiratory system and intrathoracic organs (C30–C39)		69	46	45	1
Malignant neoplasms, breast and female genital organs (C50–C58)		55	43	35	8
Malignant neoplasms, stated or presumed to be primary, of lymphoid, haematopoietic and related tissue (C81–C96)		27	18	18	1
Malignant neoplasms, human male genital organs (C60–C63)		17	13	11	1
Other ICD-10 codes in this PBC			51	35	33
PBC 10 (circulatory)	6.07	928	863	590	273
Ischaemic heart diseases (I20–I25)		523	476	334	142
Cerebrovascular diseases (I60–I69)		190	183	117	66
Other forms of heart disease (I30–I52)		75	64	48	16
Congenital malformations and deformations of the circulatory system (Q20–Q28)		18	43	13	30
Diseases of veins, lymphatic vessels and lymph nodes, not elsewhere classified (I80–I89)		36	28	22	5
Other ICD-10 codes in this PBC		87	69	54	15
PBC 11 (respiratory)	3.67	129	1835	80	1754
Chronic lower respiratory diseases (J40–J47)		57	1568	36	1532
Lung diseases due to external agents (J60–J70)		8	71	5	66
Other diseases of upper respiratory tract (J30–J39)		7	65	4	60
Other respiratory diseases principally affecting the interstitium (J80–J84)		3	26	2	24
Other diseases of pleura (J90–J94)		3	26	2	24
Other ICD-10 codes in this PBC		51	79	32	47

continued

TABLE 204 Heath forgone across specific PBCs and groups of ICD-10 codes due to the approval of ranibizumab (£80M budget impact) (*continued*)

Total change in spend analysed = £80M	(1) Change in spend (£M)	(2) Life-years foregone	QALYs foregone		
			(3) Total QALYs forgone	(4) Due to premature death	(5) QoL effects
PBC 7 (neurological)	4.78	52	873	34	838
Episodic and paroxysmal disorders (G40–G47)		10	640	7	633
Extrapyramidal and movement disorders (G20–G26)		10	72	6	66
Other degenerative diseases of the nervous system (G30–G32)		9	44	5	39
Other disorders of the nervous system (G90–G99)		2	22	1	21
Nerve, nerve root and plexus disorders (G50–G59)		2	19	1	18
Other ICD-10 codes in this PBC		19	75	13	62
PBC 5 (mental health)	14.29	103	762	67	696
Mental and behavioural disorders due to psychoactive substance use (F10–F19)		39	311	27	283
Mood (affective) disorders (F30–F39)		2	129	1	128
Organic, including symptomatic, mental disorders (F00–F09)		34	89	20	69
Neurotic, stress-related and somatoform disorders (F40–F48)		1	72	1	71
Behavioural syndromes associated with physiological disturbances and physical factors (F50–F59)		3	44	2	42
Other ICD-10 codes in this PBC		24	118	15	103

predicting how a 1% change in total spend is distributed by PBC. The same rationale is used here to establish how the additional NHS cost of £80M will affect each PBC. Hence, changes in spend reported here will be proportional to changes in spend across PBCs evaluated in calculations of the threshold (as in *Table 178*).

The estimated outcome elasticities (see *Table 157*) allow the absolute changes in spend in each PBC described above to be translated into a change in deaths and life-year effects for the 11 PBCs where mortality effects could be estimated [see columns (2) and (3) of *Table 145*]. Applying the estimated proportional effect on the mortality burden of disease to measures of QALY (including the other PBCs) provides an estimate of the total QALY effect of the change in spend in each PBC [see *Table 203*, column (4)].[ag] The QALY consequences of changing expenditure by £80M thus reflect PBC estimates of cost per QALY (e.g. for the cancer PBC, the predicted total health foregone of 211 QALYs was calculated from the change in spend of £3.58M and reflects the PBC-specific cost per QALY estimate of £16,997 reported for the threshold estimate in *Table 178*). In an analogous way, the comparison of life-year and total QALY effects allows the distinction to be made between QALY effects due the life-year effects of additional deaths and QALY effects due only to QoL [see *Table 203*, columns (5) and (6)].

The results reported in *Table 203* suggests that approval is likely to result in 411 additional deaths [see *Table 203*, column (2)] and 1864 life-years [see *Table 203*, column (3)] forgone, most of which are likely to occur in circulatory, respiratory and cancer PBCs. However, the impact of approval of this technology on QALYs forgone due to premature death [see *Table 203*, column (5)] only accounts for a proportion of the total QALY effects [see *Table 203*, column (4)]. Most (4987) are associated with QoL forgone during disease [see *Table 203*, column (6)]. These QoL impacts are most likely to occur in respiratory, neurological and mental health PBCs. The PBC-level effects in *Table 203* can also be examined at ICD-10 code level (*Table 204*) while recognising the caveats discussed in *Chapter 4*.[ah] For example, within the respiratory PBC, it appears to be chronic lower respiratory diseases (J40–J47) where most additional deaths, life-years and QoL would be forgone. In the mental health PBC the additional deaths appear to be associated with disorders due to psychoactive substance use (F10–F19) and mood (affective) disorders (F30–F39).

The impact of a reduction in the price of this technology, either through value-based pricing or the PAS that was offered during the rapid review, can also be examined in the same way. The PAS was commercial in confidence, so here we will consider the hypothetical case that a 30% reduction in NHS costs (incremental costs) would make this technology cost-effective for this subgroup of patients. Such a discount would be expected to save 1855 QALYs including 126 deaths averted, 559 life-years (359 when adjusted for quality) and QoL effects during disease equivalent to 1496 QALYs, compared with approval of the technology at the original list price (*Table 205*).

TABLE 205 Heath forgone before and after a hypothetical PAS scheme on ranibizumab

PBC description	(1) Change in spend (£M)	(2) Additional deaths	(3) Life-years foregone	QALYs foregone		
				(4) Total QALYs forgone	(5) Due to premature death	(6) QoL effects
Before PAS						
All big four programmes	16	340	1554	3259	995	2265
11 PBCs	40	389	1717	4828	1101	3727
All 23 PBCs	80	421	1864	6184	1197	4987
After PAS						
All big four programmes	11	238	1088	2281	696	1585
11 PBCs	28	272	1202	3380	771	2609
All 23 PBCs	56	295	1305	4329	838	3491
Difference						
All big four programmes	–5	–102	–466	–978	–298	–679
11 PBCs	–12	–117	–515	–1448	–330	–1118
All 23 PBCs	–24	–126	–559	–1855	–359	–1496

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